UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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NUCLEAR REGULATORY COMMISSION

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BRIEFING BY STAFF ON STEAM GENERATOR ISSUES

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PUBLIC MEETING

Nuclear Regulatory Commission
One White Flint North
Rockville, Maryland
Tuesday, February 27, 1996

The Commission met in open session, pursuant to notice, at 10:00 a.m., Shirley A. Jackson, Chairman, presiding.

COMMISSIONERS PRESENT:

SHIRLEY A. JACKSON, Chairman of the Commission
KENNETH C. ROGERS, Commissioner
GRETA J. DICUS, Commissioner

STAFF SEATED AT THE COMMISSION TABLE:

JOHN C. HOYLE, Secretary of the Commission

MARTIN MALSCH, Deputy General Counsel

PRESENTERS:

JAMES TAYLOR, EDO

WILLIAM RUSSELL, Director, NRR

BRIAN SHERON, Director, Division of Engineering NRR

JACK STROSNIDER, Chief, Materials and Chemical Engineering Branch, NRR

ASHOK THADANI, Associate Director for Inspection and Technical Assessment, NRR

MICHAEL MAYFIELD, Chief, Electrical, Materials & Mechanical Engineering Branch, RES

PROCEEDINGS

[10:00 a.m.]

CHAIRMAN JACKSON: Good morning. I'm pleased to welcome members of the Staff to brief the Commission on steam generator issues and risk and performance based rule activities.

As you know, steam generator tubes constitute a significant portion of the reactor coolant pressure boundary and therefore the structural and leakage integrity of these tubes is of particular importance because tube failure allows primary coolant into steam generators where its isolation from the environment is not fully assured.

However, steam generator tubing continue to exhibit widespread degradation mechanisms and these degradation mechanisms have caused several tube ruptures, stream generator tube leakage, steam generator replacements and personnel exposures.

Key issues associated with steam generator tube integrity include, first, the detection and sizing capabilities of the techniques and procedures used to inspect, second, the effects of both primary and secondary side environments on the degradation and cracking of steam generator tubes, and, third, the analysis methods used to assess tube integrity and the potential radiological releases associated with steam generator tube leaks and ruptures.

The Staff's ongoing rulemaking activities are designed to improve the technical and regulatory aspects for ensuring steam generator tube integrity. The current regulatory approach is prescriptive and I guess one could say lacks some effectiveness -- I won't say it's -- in dealing with some of the types of degradation, and this is what you have told me, the Staff has told me yourselves.

Degradation specific inspection and repair criteria will form the basis of the Staff's regulatory approach and so we are looking forward to hearing what you have to tell us today, and if I am right I understand viewgraphs are available and we have Exhibits A through G or something here -- so do any of my fellow Commissioners have any opening comment?

[No response.]

CHAIRMAN JACKSON: If not, please, Mr. Taylor.

MR. TAYLOR: Good morning. As the Commission may recall, the Staff did brief the Commission on these issues this past June. Since then substantial progress has been made in developing generic guidance more appropriate for certain forms of degradation being experience.

Unfortunately, new forms of degradation are being detected and other previously-known forms are being more widespread. In my opinion, this is one of the more serious challenges facing the industry today, and you will hear about that today.

At the table with me from NRR are Bill Russell, Ashok Thadani, and Brian Sheron, Jack Strosnider -- where is Jack? Okay -- and from the Office of Research, Mike Mayfield.

Ashok Thadani will begin the briefing.

MR. THADANI: Good morning. May I have the Viewgraph Number 1, please?

Actually, Chairman, you have very well covered some of the things that I was going to say, I'm sure better than I would have done, but nevertheless it would probably be useful --

CHAIRMAN JACKSON: I probably learned it from you.

MR. THADANI: -- to go through some of the background as to the importance of the issue and generally the approach that we are using and then Brian Sheron is going to go through the recent inspection findings, some of the implications, short-term actions that we have taken, and where we are proceeding in terms of long-term actions. Finally,, he will also briefly describe the discussions that took place at an international conference on steam generator tubes in Chicago last October -- because it is clearly as Mr. Taylor noted -- this is a big issue not only here but in other countries as well.

May I have Viewgraph Number 2.

Again, as Mr. Taylor mentioned, the integrity of the steam generator tubes is not only an important safety issue but it has significant economic implications as well. If a large number of tubes are degraded, they have to be plugged or sleeved. If a significant number of tubes are plugged, that could impact the ability to generate full power because of loss of heat transfer area, and sleeving of course is an expensive process in itself and could become a critical item during outages, so there is significant economic implication.

In addition to that, up to now 12 plants have actually replaced steam generators because of various forms of degradation and --

CHAIRMAN JACKSON: Let me stop you for a quick minute. Can you tell me what rough costs for replacement?

MR. THADANI: To replace them? Yes. In fact --

CHAIRMAN JACKSON: If you are coming to it, I can wait.

MR. THADANI: No -- no, no. I wasn't planning to. We have got some estimates from Electric Power Research Institute. Technically, the cost appears to be if they are two loop plants, two steam generators, they run $50 million and up -- in some cases, significantly above that.

Typical costs seem to be on the order of about

$100 million. Now I say typically because you can see some cases where the cost has been well above $100 million, in other cases somewhat below $100 million, but that is generally what we are talking about.

CHAIRMAN JACKSON: And some of that, does it not, have to do with how the containment itself has to be dealt with?

MR. THADANI: Yes, that certainly impacts.

CHAIRMAN JACKSON: Whether the hatches have been designed to remove them --

MR. THADANI: Yes.

CHAIRMAN JACKSON: -- versus having to do -- what is it, ginnae?

MR. THADANI: Yes.

CHAIRMAN JACKSON: To actually have to --

MR. THADANI: They have to actually cut a big hole in the containment in fact, so this can be a tremendously intensive activity. It takes a fairly long time period and it is quite expensive.

Twelve plants have actually replaced the generators so far, and as I understand it, again talking to Electric Power Research Institute, that 10 plants have placed orders to replace their generators in addition to the 12 plants.

So I think it's clear that it is -- besides the important safety issues there are economic issues, and our focus, of course, is safety, and as you, Chairman, noted, the steam generator tubes do form a significant portion of the reactor coolant pressure boundary and we are talking about tens of thousands of tubes that have to bè monitored to make sure that the integrity is maintained.

Again, as you noted, the integrity of the tubes play a critical role in terms of overall safety.

First, these tubes form the boundary of the reactor coolant pressure. Failure of those tubes can also lead to bypassing containment because you can get leakage or whatever flow you get from primary side to the secondary side into the steam generator, and normally if the pressure is high enough the safety relief valves will open on the secondary side of the steam generators and now you have created a pathway directly to the environment from the primary side, so in this case you have lost two barriers. The whole concept of defense in depth is to maintain a number of barriers. With one of these accidents you can lose two barriers -- the primary system as well as the containment boundary, so it is a very important safety issue.

Now we also know that really a significant impact on the public health would be if there is substantial fuel damage as well, but that would require failure of additional systems that are in fact provided to mitigate an accident of this type.

If those failures were to occur, then clearly the pathway exists for significant releases to the environment.

Now in the U.S. up to now there have been nine steam generator tube rupture events. It seems as though we see one event about every two to three years.

MR. TAYLOR: Those are individual, right?

MR. THADANI: Yes, single. Yes, yes -- single tubes in this country. In all those cases the safety systems functioned and the operators have taken appropriate action, so the consequences have been minimal in terms of impact.

CHAIRMAN JACKSON: So following up, there has never been a multiple tube rupture that has occurred at one time?

MR. THADANI: That's correct, that's correct.

MR. TAYLOR: There have been other ruptures in other countries too.

CHAIRMAN JACKSON: Of more than one tube?

MR. THADANI: No, one tube.

CHAIRMAN JACKSON: Always one tube.

MR. THADANI: Always one tube. We don't know of any case where there have been more than one tube failures and we know of at least two such events in other countries -- single tube ruptures, that is.

So the challenge really I think is simply to -- it would be worthwhile to see if there is a way the frequency of these events can be reduced, but the real concern is are these new degradation mechanisms such that the potential for such failures may in fact increase with time? That is an issue that needs careful attention.

Could I have Viewgraph Number 3, please.

I thought I'd very briefly go over what our current requirements are because that will then tie in to what we are trying to do in the future.

There are basically design requirements and then there are operational constraints. In terms of design requirements under Part 50 of the Code of Federal Regulations, we have a number of general design criteria. The real thrust of these criteria basically is to make sure that the likelihood of leakage from steam generator tubes is maintained at very low levels and that there are enough margins built into the design so that even from consequential failure point of view -- that is, if you have an event that causes increased pressure or pressure differential from primary to secondary side, that the integrity of the primary system is maintained, so the general design criteria go to a very general set of requirements.

These requirements then are followed up on through inspection, period inspection and testing.

Again the general design criteria do call for a capability for inspection and testing.

COMMISSIONER ROGERS: Do the general design criteria specifically address steam generators?

MR. THADANI: Yes, it does.

COMMISSIONER ROGERS: Specifically steam generators rather than the pressure boundary?

MR. THADANI: In the context of inspections, yes. They address the whole reactor coolant pressure boundary.

CHAIRMAN JACKSON: In each part of it you are saying?

MR. THADANI: Yes. Yes, that is, they address the whole reactor coolant pressure boundary. That picks up the steam generator tubes as well.

COMMISSIONER ROGERS: Specifically mentioned in there?

MR. THADANI: In the GDC, steam generator tubes -- I don't believe they are specifically mentioned.

COMMISSIONER ROGERS: I am under the impression that they are not.

MR. THADANI: I do not think they are specifically mentioned but they are picked up as part of the reactor coolant pressure boundary.

COMMISSIONER ROGERS: But it is just in general terms?

MR. THADANI: Yes. It is in general terms, and this is where then you go from general design criteria to the technical specifications wherein then you pick up specifically what you have to do with the steam generator tubes, so it is implicit, but I don't believe it is explicit in the GDCs, yes.

There are two parts. They are the design criteria and then the steam generator tube rupture in itself is considered one of the design basis accidents, which means that you postulate in this case -- I think that is a rather foolish word for me to use, postulate. We have seen a number of events that have happened.

So you can see the steam generator tube rupture. You have conservative methods to analyze what would happen and these conservatisms are not only in methods but also in terms of initial conditions. That is, you do assume a certain amount of leakage from primary to secondary and so on.

The whole idea there then is to make sure that the consequence to this accident when analyzed conservatively would not exceed the guideline values in 10 CFR, Part 100.

CHAIRMAN JACKSON: I think Mr. Taylor, you have looked up the --

MR. TAYLOR: I was going to read it. It's very short but I think I have the right criterion and you guys correct me -- it's Criterion 14, and it is reactor coolant pressure boundary: "The reactor coolant pressure boundary shall be designed, fabricated, erected, and tested so as to have an extremely low probability of abnormal leakage, of rapidly propagating failure and of gross rupture."

COMMISSIONER ROGERS: That's right, but it doesn't say steam generators --

MR. THADANI: No, it does not.

COMMISSIONER ROGERS: It applies to both BWRs and PWRs.

MR. THADANI: Right.

COMMISSIONER ROGERS: There is one more level of detail one might be able to go into.

MR. THADANI: Yes, and then GDC 32 picks up on the inspection and testing aspects.

CHAIRMAN JACKSON: Mr. Russell.

MR. RUSSELL: In this case, we typically endorse the ASME Code and so the differential pressure criteria that is used, which in this case got embodied into some regulatory guides which then are incorporated in the technical specifications, we typically use 1.4 times the maximum differential pressure under a steam line break or a three times of normal differential pressure are the two structural criteria and they flow from the Code into regulatory guidance, which goes into the technical specifications.

MR. THADANI: Okay, and then in the technical specifications of course is the requirement for performing inspections and their acceptable limits if those limits are exceeded. In this case, generally the acceptance limits are a way stage -- the way stage of thinning of tube walls, which is very easily picked up through any current testing, and if that limit is exceeded then they have to take corrective action.

The other aspect that is picket up in the technical specifications again relates to making sure that if there is a certain amount of leakage from primary to secondary that the plant is shut down, because that is clearly an indication of problems that could grow and get worse with time.

Also, the limit that is allowed, leakage limit that is allowed, is consistent with the calculations that are done in terms of meeting 10 CFR 100 guideline values.

In addition to that, there are limits on the activity level in the primary system which would be indicative of if there is any fuel problems with the fuel.

If the activity level goes up above a fairly low level, then the plant has to be shut down again, so those are operational considerations.

Now these -- at least in terms of the two degradation and inspection activities, the criteria are fairly old. They were developed over 20 years ago and they were based on an understanding at that time as to what kind of degradations were being seen, and as you have heard and you will hear again -- Brian Sheron is going to go into some details of what the inspections are showing the forms of degradation -- and it's clear that those technical specifications that we have in place are not sufficient in addressing these new forms of degradations.

In some cases, quite frankly, these criteria are probably conservative actually because when you take into consideration structural capability and leakage requirements in some cases one could actually permit some, certain types of cracks could be well beyond the 40 percent limit that's used today in the technical specifications, so we do need to make our requirements consistent with our best understanding today of the degradation mechanisms as well as safety factors.

May I have Viewgraph Number 4, please.

The issue has been around for quite some time, particularly when steam generator tube rupture events took place from the mid-'70s on, concern was mounting as to potential safety implications of these events, and the

Agency initiated what was then called unresolved safety issues -- Unresolved Safety Issues 3, 4 and 5, related to the steam generator tube rupture events.

Fairly extensive evaluation was conducted. The evaluation included consideration of spontaneous tube failures as well as consequential tube failures -- spontaneous tube failures as an initiating event; consequential tube failure -- that is, postulating certain other accidents, like if you have a steam line break event, which will cause fairly large pressure differential across primary and secondary, what is the potential for tube failures?

Another accident that was considered was anticipated transients without scram. There the primary pressure will go fairly high, again the focus being large pressure differential from primary to secondary.

Not only that evaluation, which was documented in NUREG-0844, but also some of the recent individual plant examinations that we have looked at, they all basically concluded that the risk from these tube ruptures, either spontaneous or consequential, from those design basis events was not very high. In that sense, that is the estimates are coming out somewhere around 10 to the minus 6 per reactor year of having a potentially significant release.

If you look at the individual plant examination, the range appears to be 10 to the minus 5 to 10 to the minus 6, but generally clustered around 10 to the minus 6 per reactor year.

CHAIRMAN JACKSON: This is looking at the probabilities for both spontaneous as well as consequential tube ruptures?

MR. THADANI: Consequential tube failures from the events I am describing because I am about to come to an issue that we have not addressed in the cost.

CHAIRMAN JACKSON: I will wait and hear you because I was going to ask a question.

MR. THADANI: Yes, there is -- to me this is -- it was the best evaluation we could have done given the understanding we had, but I think there are some new issues that we have to deal with.

So since then, since these studies have been done, there are at least two new issues. One is the degradation mechanisms and Brian is going to discuss some of the results that we have seen recently and the types of degradations that have been seen.

CHAIRMAN JACKSON: Let me ask you that. Is he going to speak then in terms of the consequential tube failure?

MR. THADANI: I am going to --

CHAIRMAN JACKSON: Let me finish -- in terms of the impact of degradation on the risk probabilities?

MR. THADANI: I will briefly cover that and then Brian will go into the specific mechanism aspects.

CHAIRMAN JACKSON: Very good.

MR. THADANI: If you stand back and look at some of the -- many of the studies that have been done to date, it does appear that the biggest risk to public health and safety comes from accidents that lead to substantial fuel damage where the potential exists for either early containment failure or bypassing the containment.

There are sequences when you can bypass the containment. Intersystem LOCAs have been ones that gotten a lot of attention in the past because they bypass containment. They also lead to damage of mitigating systems, so they can lead to large releases.

Early containment failure takes place following substantial fuel damage -- again there is the potential for significant releases.

Now the other pathway is the steam generator tubes. You would in fact if you have substantial fuel damage and you have lost integrity of the steam generator tubes, you would in fact calculate fairly significant releases also.

So what are those conditions then where if you do have fuel damage, substantial fuel damage, you want to be careful, you want to know would the steam generator tube integrity be maintained, because if it is not then I think you would get substantial releases.

What we have found is that there are certain accident scenarios where the potential certainly exists that the tubes' integrity may be lost, particularly if the tubes are significantly degraded.

The kinds of accidents we are worried about, those that lead to high pressure and high temperature condition in the primary system, we have been so worried about these types of accident sequences that we as an agency have done extensive research, many years of research, on how the containment would behave, and we have at many national laboratories done lots of experiments to make sure we have a good understanding of what would happen.

What we have not done has been to see -- while we gained confidence in terms of containment performance for these accident conditions, we don't have the same level of understanding or information on the steam generator tubes and so that has become the key issue now.

There are a number of factors that we have to look at -- if I may go to Viewgraph Number 5.

There are a number of factors that we have to look at and I will touch on each of those factors, but it is clear to us that we do need to come up with an approach that fully considers risk aspects. It is today -- up to now I think it's captured most of it but not all of the factors, and we need to also capture the new degradation mechanisms, so that has been the driving force for saying let's take a fresh look at the issue and come up with something that is consistent with today's thinking.

In terms of trying to make this approach risk informed, we had to look for some guidance and the guidance we looked at is the Commission's safety objectives, which are of two forms. One is to make sure that the core damage frequency is low enough. In this case, that's a value of about 10 to the minus 4 per reactor year. I don't see that as a problem at all in this case we are talking about.

But there is another consideration that is limit the potential for large releases to something like 10 to the minus 6 per reactor year is the other subsidiary objective. That is a challenge. That is the real issue that I think we have to carefully assess, so in order to get an understanding of risk implications, we need several pieces, we need to develop several pieces of information.

First is what is the frequency of spontaneous tube ruptures? I don't see that as a problem. I think we know fairly well. Unfortunately, it's higher than what we would have liked, given the experience that we have, but we also need to understand what's the probability of these tube failures if some other events take place.

I describe that design basis type accidents have already been addressed. What has not been addressed has been these high pressure, high temperature scenarios that could lead to consequential failure of the tubes, and the tubes' integrity is pretty sensitive to these conditions.

May I have Viewgraph Number 6, please.

MR. RUSSELL: Ashok, it might help to just illustrate with one example what kinds of scenarios we are talking about. Station blackout, where you lose AC power, followed by a loss of secondary heat sink -- for example, a turbine-driven aux feedwater pump -- so on a typical PWR if you were to have a blackout scenario and then lose your turbine-driven aux feed pump, you would have a situation where you would not have the heat sink. The steam generator would relieve through the atmospheric dump valves or through the relief valves and then you would have a boil-off from the primary side through the safety valves and you would have a very high differential pressure across the generator.

Under that condition you could proceed into a high pressure melt type scenario --

COMMISSIONER ROGERS: What is the --

MR. RUSSELL: -- and that is the consequential failure of the generator. The events going on was not the spontaneous rupture, and now you are challenging the generator, and then if you have a generator that has significant degradation, cracking, et cetera, what is the potential for bypassing through that generator?

COMMISSIONER ROGERS: What is the design for the pressure differential, primary-secondary pressure differential? What is the design --

MR. RUSSELL: The design is three times the normal differential pressure, so you are typically talking about 1100-1200 pounds of the normal differential pressure, and so three times that would be about 3600?

MR. THADANI: Right, about 3600.

MR. RUSSELL: Would be the design --

MR. THADANI: Yes.

MR. RUSSELL: Typically the actuals for testing are much greater than that.

CHAIRMAN JACKSON: Yes, they are like 9000.

MR. RUSSELL: 8000-9000 or greater.

MR. THADANI: So the key again --

MR. RUSSELL: It's when they are degraded that you don't have that same margin.

MR. THADANI: Yes. I think, Bill, that is -- I am glad you brought that up because what you are worried about is really loss of secondary cooling, because when you lose secondary cooling, primary pressure and temperature is going to go up, and if it is elevated and you are not able to provide some high pressure make-up capability, with time you'll uncover the core, damage fuel, and you'll create very challenging flow paths because the center of the core is going to be very hot. You'll create internal recirculation paths and that, incidentally, does play a part, because the key point is to get an understanding of the temperature that the steam generator tubes see, and so it is important to understand these phenomena from a thermal hydraulic point of view.

The first piece that we have to be sure we understand is what is the frequency of these types of events that lead to elevated pressure and temperature in the primary system. It is generally, from the IPEs and PRAs that we have looked at, the frequency is in the range of 10 to the minus 4 to 10 to the minus 5 per reactor year.

That is, it is high enough to say we are concerned about it. We have got to probe further to see where we go.

Then the second part is for these -- we need to understand pressure temperature conditions for these scenarios.

As I said, phenomena are complex and we also know upfront that there is sensitivity -- the behavior of the tubes to temperature and pressure, so we do need to make sure we have good understanding of that.

Once we identify the profile in terms of temperatures and pressures, then we want to take a look at all the reactor coolant pressure boundary, not just the steam generator tubes, because there may be competing effects, different parts of the primary system may in fact be more susceptible to these conditions than the steam generator tubes.

But then steam generator tubes play kind of a unique part in that we allow a certain amount of degradation to take place and it is permitted, so we want to try and understand under these conditions different -- starting with clean, brand new tubes all the way to significantly degraded tubes -- we need to understand how they behave.

The Office of Research has initiated activities at Argonne National Laboratory, where experimental work will be beginning fairly soon. In fact, Brian and I are going there I think this Sunday, I believe, to see where they stand and experiments should be beginning the middle of next month, I think, or perhaps a little later.

CHAIRMAN JACKSON: This is on which aspect of these?

MR. THADANI: This is going to be high temperature, high pressure conditions and different types of tubes with different flaws, to run through and get an understanding of the behavior.

It is an issue, as you will hear later on, it's very important. We want to do it right, do it as well as we can, and it is the pacing item and it is impacting the schedule.

CHAIRMAN JACKSON: Let me ask you this question. You are talking on, you know, our side in terms of what the Staff is doing and this is significant --

MR. THADANI: Yes.

CHAIRMAN JACKSON: How sensitized is the industry? What are they doing?

MR. THADANI: It's the next viewgraph that has a thought on it, but I might as well address it now.

CHAIRMAN JACKSON: I promise you I didn't peek.

MR. THADANI: It is an issue where industry has only recently begun to take it more seriously than they had up to now. Bill Russell and I at many of the steering group meetings have been pushing the industry. I mean there is no question in my mind that they have been very slow.

Even today I think there is a great deal of apprehension on the part of the industry as to are we bringing in the issues, the severe accidents into licensing considerations, and our view simply has been that as we go forward into new rules, regulations and so on, we do need to make them fully risk-informed consistent with the level of safety that we would like to see out there.

I would say recently the industry has begun to initiate a fair amount of work of their own. They have resolved some technical issues. There were issues on fission product deposition and so on, some severe accident issues. They have come in and addressed some of the uncertainties on estimating pressures and temperatures, and again there are some key technical issues that they have focused attention on.

I am seeing signs of moving in this direction, for whatever purposes -- maybe it is defensive -- but nevertheless they have initiated a number of studies of their own.

CHAIRMAN JACKSON: Mr. Russell.

MR. RUSSELL: I would like to go back to one issue that was mentioned earlier so that we don't leave a wrong impression with the Commission.

It would be a favorable outcome if there were some other portion of the reactor coolant pressure boundary which would fail before the steam generator tubes, because then we would be back with it contained within containment because that would be a release into containment.

So for example, if a reactor coolant pump seal, which has to have water to really function, if the seals provided enough of a let-down path for the gases such as you did not have the pressure and the temperatures in the steam generator tubes, that would be a favorable outcome -- or if the pressurizer surge line were to fail, you would depressurize into the containment and you would contain the high pressure melt scenario within a large, dry containment.

I didn't want to leave the impression that the work we are doing -- we are focusing on the tubes to understand whether the tubes are going to fail before some other component under this scenario, and we would really prefer to have something else be the weak link rather than have the bypass.

What we are not sure of is when you get degradation in cracking that you will hear about or you may have a few thousand tubes which have cracking, how will those cracked tubes behave under conditions of high temperature, high pressure? That is really the focus of the research, to get us some hard information on the behavior of the tubes under these conditions as well as determine what are the likely conditions which would exist in a steam generator under one of these scenarios.

MR. THADANI: There's some very interesting challenges. Pressurizer surge line clearly is one potentially weak area. Pump seals may be another one. But these are not only -- there are really three variables.

I have been talking about pressure and temperature but time is another critical variable in this, and so there can be competition and timing may become a very important factor and it could become -- it could be either fairly clear what will go first, or it may get pretty difficult to come to grips with what is going to fail first, and these are really some of the difficult issues.

We are still working on it, and --

CHAIRMAN JACKSON: Some of this is going to come out of this program that you are talking about?

MR. THADANI: Yes. We are doing two things -- a program -- what that would lead to would be development, because we cannot literally do thousands of experiments but we will develop a model from these experiments. We will use the model to evaluate different combinations and conditions.

In parallel, we are doing a number of thermal hydraulic analyses to try and make sure we have a reasonably good understanding of these conditions.

Now industry has also done calculations. My understanding is we are coming together, we are getting closer. We were a bit apart a couple of months ago, but we are coming closer to agreeing on what these conditions would be, so at least we have made some good progress in that area.

MR. TAYLOR: I was going to say just one or two things.

As I understand it, this research will be done and we will try to model defects by machining and our otherwise instituting the defects in this testing.

I consider this to be very, very important research and support it fully, financially and otherwise, to try to get this research.

CHAIRMAN JACKSON: But you are saying -- let me make sure I understand. At this point, though, the industry itself does not have any comparable kind of research program?

MR. RUSSELL: Not that I am aware of it -- actually looking at the behavior of degraded tubes under these conditions.

MR. THADANI: I would like Jack to address that.

MR. STROSNIDER: The industry evaluations up to this point were based on a limited amount of material properties data at the kind of pressures we are looking at and trying to extrapolate fracture mechanics models that are used at lower temperatures to these higher temperatures to see if they really work, so they have done evaluations using the limited data that are available but we need to confirm the applicability of the models and to get more data at these higher temperatures, so the only work I am aware of at this point in time would be that it is going to be performed by the NRC Research Office.

MR. RUSSELL: There is one other aspect that I think it is important to understand, and that is that different plants may have different susceptibility to loss of secondary heat sink. The ability to depressurize is quite important so having power operated relief valves where you can use the power operated relief values to potentially depressurize can be helpful.

In fact, the new designs are actually going to the point of complete depressurization, AP-600 for example, and we look at the reliability of the depressurization systems as well as the capability to mitigate high pressure scenarios.

Some plants don't have power operated relief valves. For example, Palo Verde, the CE design, which we did have the one event, does not have power operated relief valves. They use pressurizer spray, and so there you would not be able to use this to depressurize, so there may be different classes of plants which have different susceptibilities, so we need to also evaluate this in the context of various plant designs -- so there is not a generic PWR. You also need to apply the plant-specific design features.

CHAIRMAN JACKSON: Right.

MR. THADANI: In that viewgraph under "frequency of relevant sequences," the part that says design factors, that is really the issue.

I think we will end up with probably two classes of plants, ones that do have PORBs and ones that do not have PORBs, because it may be that in the context of accident management the depressurization capability would be very important.

Now even beyond AP-600, under System 80-Plus, which was the Combustion Engineering advanced light water reactor design, they -- the design includes in fact a safety-related depressurization system which was -- the design of which is in fact based on high pressure melt sequences, so today we are actually dealing with it in a fairly upfront, straightforward way.

CHAIRMAN JACKSON: I had one last couple of questions. Is the schedule for the research program that you just described such that it will be able to provide timely input to the rulemaking activities?

MR. THADANI: You had asked me that question earlier and I indicated to you that what we are doing right now is systematically going through each of the technical issues and seeing what is the best we can do, and I had indicated to you that we were going to put together a paper on that.

In fact, what we will probably end up with is going to be, while the research program can go on for a longer time period, but we want to get some of the critical information upfront that we can use.

You see, the reason -- and I don't want to come back with a change in schedule unless I have some confidence that we are really going to meet that schedule -- what we have to do is not only generate this information, it's critical information, for us to then go do our regulatory analysis and it's clear to me this issue is so significant that it is going to take fairly extensive interactions with the Advisory Committee as well on Reactor Safeguards. There is no question in my mind it's going to be a very extensive dialogue.

What I have asked the Staff to do is to take each of the issues, clearly state what we can and cannot do by what time period, and then that is the information we will provide to you in a paper.

CHAIRMAN JACKSON: Consistent with doing it in the way that you said?

MR. THADANI: Yes, it will be consistent --

CHAIRMAN JACKSON: Careful and so on.

MR. THADANI: Yes, indeed.

COMMISSIONER ROGERS: Just before you move on, just on this research project, to what extent are your sample tubes going to have some kind of a water chemistry history that at least looks at maybe the worst cases that we have seen in the industry?

MR. THADANI: I think I would like Mike, perhaps, to answer.

MR. MAYFIELD: Let's separate the program if we can into the work that is being done to support the severe accidents research and then the balance of the research program.

The work being done to support the severe accidents issue will use machine defects as a first cut because we know that at these kinds of conditions the notches simulate what goes on because of the plastic deformation near the real crack tips. That is not much of a concern.

In the balance of the research we are going to some lengths in fact to create water chemistry conditions that look like what we think we see in service to create defect structures that look like what we see in service and going to some lengths to replicate conditions so that the defects we generate that are used in the subsequent testing look like what we see coming out of service.

We are also building, the intention at least is to gather tubes from retired generators and perform testing on those.

CHAIRMAN JACKSON: Are you also going to be looking at crack growth mechanisms and rates?

MR. MAYFIELD: Not so much rates.

MR. RUSSELL: We'll ask Jack to address that when we get into that portion of the discussion.

CHAIRMAN JACKSON: Okay.

MR. RUSSELL: Because what we are focusing on now is what I will characterize as the safety significance side, and I would state that we need to make progress on the rulemaking and if we are not able to get all the answers through a research program we still have real issues with respect to our structure.

We are back at a draft regulatory guide, tech specs which vary from plant to plant. We are not doing this is a consistent manner, so there are a number of things we need to address and we believe we have a regulatory structure that we are posing that would allow new types of degradation, new information to be factored into the process, so I am interested in getting a process in place that can be a living process as well, so if we are not able to get all the research done to support the rulemaking, we still want to be on a fast track for the rulemaking.

CHAIRMAN JACKSON: Okay.

MR. THADANI: Okay -- if I may go to Viewgraph Number 7, which in the interests of time I would say that we have actually discussed this already and Brian is going to really go into some of the details of some of the degradation-specific management activities that we have ongoing as well as describe the framework of the rule and where we are.

MR. SHERON: Let me talk quickly about tube inspections.

Next slide, please.

As Ashok said, most plants have tech specs which were developed probably back in the '70s when wastage and thinning was their predominant form of degradation mechanism.

The probes that were capable of detecting that was considered to be like a standard bobbin coil probe. Since then, with these newer forms of degradation that we're seeing, predominantly in the form of cracks, the industry has responded. There have been improved probes developed for detecting these kind of cracks both in axial and circumferential orientation as well as improved data analysis.

This is a standard three-coil RPC probe which has two pancake coils on it and what you may have heard as a plus-point. I could pass that around.

This is put on the end of a long plastic tube, which we have actually got one here to see, and it goes right up into the steam generator tubes and as it passes by a defect it works on the impedance principle, where you measure the impedance of the coil in there and by looking at the phase angle of the impedance, if you remember your electrical engineering, you can actually distinguish a crack versus, say, a geometry difference or something, and that is how one determines whether or not we have a defect in a tube.

Using these improved probes like you have seen there, one of the consequences is we are capable of detecting degradation earlier than previously.

Before, for example, a regular rotating pancake coil in general has a sensitivity threshold of about 40 percent through-wall so in other words usually it was capable of detecting cracks once they exceeded a 40 percent through-wall depth.

Some of the newer probes we have seen, like plus-point probe which is on that coil there, seem to be able to detect may down as early as 20 percent, 30 percent through-wall.

While these cracks may not be structurally significant, one of the difficulties is that the ability to accurately size them is still eluding the industry in terms of being able to correlate them. As a consequence, they have to assume that the indications that they see in fact exceed their tech spec criteria, and therefore they either have to plug or repair the indications.

The other thing that we are learning is that stress corrosion cracking continues to be the dominant degradation mechanism in the steam generators.

MR. RUSSELL: Certain kinds of cracking --

MR. SHERON: Well, I think it's both the axial and the circumferential.

We see it in various places. The circumferential cracks usually occur at the top of the tube sheet where there is an expansion. Axial cracks typically can occur in a free span of some tubes. They can also mostly occur in the Westinghouse generators at the tube support plates where they pass through, if you'll see on these tubes here, the metal rings that you see around are what are used to simulate the tube support plate locations. That will give you an idea of the clearance. These are drilled hole support plates, as opposed to other kinds like a quatrefoil and so forth where there is maybe -- the metal is like in a mesh and the tube sits between it.

There is not much clearance in there and you get a buildup of corrosion products which aid in both the cracking as well as the phenomenon called denting.

Circumferential cracks -- and we have some machined examples here which you can see, which were machined in -- this right here is actually a 360 degree through-wall crack. The reason you see this is here is so that the tube doesn't fall apart.

This is used so that when they put a probe up to see how well it can detect the circumferential cracks, we have seen large indications at some plants just in this recent fall outage at Arkansas Unit 2, Braidwood, Sequoyah, Salem -- Byron has seen at their recent outage something on the order of 2700 indications in the generator.

CHAIRMAN JACKSON: What would have been the implication for a main steam line break at Maine Yankee?

MR. SHERON: Maine Yankee went in after they detected the circumferential cracks and they did pressure test, where they actually go in and they put a blotter in the region where the crack in, right above the tube sheet where the circumferential crack is, and they actually pressurized it to above the 5000 pounds or so, which is the design Delta P across the tubes, and they did not fail.

One of them I believe did exhibit some leakage, okay, but what they showed was that even though these tubes had circumferential cracks, they did retain their structural integrity and did retail the margins required by the ASME Code, so they were considered to still meet the structural limits.

MR. STROSNIDER: Brian, excuse me. I just thought I might mention that they also did a leakage analysis and with regard to Part 100 dose limits and concluded that they would not have exceeded or reached that under-postulated accident conditions.

MR. SHERON: One of the reasons is that the type of circumferential cracks which they observed were not a single coplaner crack but they actually exhibit sort of a micro-crack feature over a very short band, and what you see is ligaments in between which give greater strength.j

As I said, right now the industry has not really been able to quantify depth sizing of circumferential cracks as well as growth rates, which you mentioned earlier. As a consequence, since they cannot really tell you how deep a crack is or how much it will grow during the next cycle, they are basically required to plug or repair these kind of cracks upon indication.

The other thing is that because they can't really quantify the depth of the rate of growth, a number of plants we have put on a mid-cycle inspection because they cannot really justify that they can go a full cycle of 18 or 24 months and demonstrate that cracks will not initiate and grow to an excess of the tech spec or the structural requirement.

CHAIRMAN JACKSON: This is where you have seen significant indications?

MR. SHERON: Yes.

CHAIRMAN JACKSON: All right.

MR. SHERON: Braidwood, for example --

MR. RUSSELL: Or the result of events.

MR. SHERON: Braidwood for example was really unable to justify being able to continue another 18 months, so right now they will be shutting down in September, I believe, to do a midcycle inspection.

CHAIRMAN JACKSON: I see.

MR. SHERON: The next slide, please.

Dent inspections -- we've seen axial cracking due to primary water stress corrosion cracking and circumferential cracking have been found at dented intersections at a number of plants.

There is a tube out here -- I believe the one you have -- which actually -- no, I'm sorry, not that one. There is one here which actually simulates some dents which are -- as the tubes pass through the tube support plates to get corrosion products which actually build up and have a volume which increases and actually crushed the tube, you might say, so it closes down.

We have seen in the past some dents so large that you can't even pass one of these probes through the tube. We have seen now though that some tubes which have minor denting, which means you can still pass a probe through, are now exhibiting cracks.

Diablo Canyon, Sequoyah and Salem, for example, are some plants that have seen this kind of cracking. However, prior to that I think only North Anna was the only plant that we had seen this kind of phenomena.

Axial primary water stress corrosion cracking is also being found at intersections with small dent signals and this is occurring, unlike the Westinghouse plants where we just issued this Generic Letter which had an alternate repair criteria for outside diameter stress corrosion cracking -- these cracks are occurring on the inside, the primary water side and some of the cracks are extending beyond the tube support plate which is different because in the Westinghouse case for the outside diameter stress corrosion cracking the cracks were pretty much confined to within the tube support plate region.

CHAIRMAN JACKSON: This somewhat relates to Commissioner Rogers' earlier question about chemistry.

The materials that are used, that's a well-documented, well-known what the materials are?

MR. SHERON: Yes, it's alloy 600 in most steam generator tubes.

CHAIRMAN JACKSON: Okay.

MR. SHERON: Alloy 690 is now being used, I believe, for replacement generators as well as for sleeves. This is much more resistent to stress corrosion cracking.

Jack?

MR. STROSNIDER: I just wanted to point out one thing. As Brian mentioned, this is different because it is primary water stress corrosion cracking.

Getting back to the chemistry issue, this is significant because primary water chemistry is very well controlled and what this tells us is that in these areas where you have high residual stresses, basically it is just, stress corrosion cracking is a time-dependent phenomenon. It is catching up with some of these plants and it is not as dependent upon secondary water chemistry control, so it could affect plants regardless of how well they have controlled their chemistry. That is not a good trend but that is something we have to be aware of.

MR. SHERON: Yes. One thing we do see is where this cracking usually occurs -- and I say usually, not in all cases, is where there are high residual stresses.

Where they expand the tube into the tube sheet there is a slight expansion -- there is a transition region -- and usually there is a high residual stress where the tube was physically bent.

Anywhere we see these high residual stresses is where we are now seeing cracks start to occur.

The next slide, please.

Sleeve joint cracking -- as a result of the Maine Yankee inspection, we issued Generic Letter 9503, which basically documented the experience that Maine Yankee had. It pointed out that when one uses more sensitive probes such as the plus-point and more advanced probes, that one will actually see degradation that one does not see using the more conventional probes, and indicated that when Maine Yankee went back and looked at a previous inspection result, what they found is that using the newer techniques that they had at that time -- I mean at the current outage from the previous outage -- they found that there were indications that they probably should called as cracks that they did not, and so we have through the Generic Letter asked the industry to make sure they go back and look at previous outage results and make sure they have not missed any indications that they originally thought might not be a crack.

We also see indications now at sleeves where they have been installed -- the way, for example, in a Westinghouse hybrid expansion joint sleeve, and there is an example here on the table I believe --

CHAIRMAN JACKSON: Oh, the --

MR. SHERON: Actually, if you feel it, you can feel -- if you run your hand down, you'll feel where the expansion is.

CHAIRMAN JACKSON: We'll look at it afterwards.

MR. SHERON: But again they are seeing cracks now in the parent tube, not in the sleeve but in the parent tube, where it was expanded. The way they put these in and sealed them is they first go in and do a hydraulic expansion so they get the sleeve to just contact the parent tube, and then they go in with a hard roll device which actually rolls the sleeve and expands it into the parent tube, so there is sort of an expanded region where it is of larger diameter.

They are seeing cracks at these transition regions between the hard roll and the hydraulic expansion.

What is critical about that is where these cracks occur. If they are occurring in the lower part, then there is still a lip that exists so the tubes can't physically separate, but if these cracks occur above that, then there is no lip that will hold it in place and they could theoretically just slide apart.

Plants that are seeing that are Kewaunee, Point Beach and Cook. We have been in discussions with them. They have proposed criteria where some sleeves that exhibit these cracks, if they can convince us that the cracks are occurring below this lip so that there is still basically a lip to hold them in place, then they would propose to leave those tubes in service.

However, if they find the cracks go above this, then they would take them out of service either through plugging --

CHAIRMAN JACKSON: So at this point most of the sleeves are mechanical essentially?

MR. SHERON: Yes.

CHAIRMAN JACKSON: What about electro-sleeve?

MR. SHERON: Well, there are several different kind of sleeves right now under development by the industry. Westinghouse, for example, has been looking at a thing called a direct welded repair in which you put actually a small laser up in the tube and you basically melt the tube and remelt it and reform it right on the spot.

There is another one which you will see some examples there and which is a weld overlay, which you actually go in and put a weld overlay over the cracked region. That small sample down there, you'll actually see two cracks that were machined in and then you will see the overlay on the inside.

That is another possibility and then we also understand that there is an electro-plating proposal I think by Combustion -- I'm sorry, B&W.

Again we need to see -- none of these have really been used in service in any U.S. plant -- oh, no, I take that back, I'm sorry. I think there's a couple of them.

MR. STROSNIDER: The nickel-plating process has been used in Canada and anticipating that we will get that submitted, I think we're going to take a look at that and see how it is working.

MR. SHERON: But we have no submittal in-house yet with regard to these advanced methods. The vendors are working on the process controls and implementing this, you know, field implementation of these techniques and making sure they have something that is inspectable, but we anticipate that we will see this in the near future.

MR. THADANI: In fact, yesterday we chatted about it a little bit. It turns out that at Pickering they have applied this and they have about a year and a half's experience roughly I think, but we are going to look into this further.

MR. SHERON: One of the problems, you know, why this hasn't been implemented widespread is that there is still process control problems. I think there are some examples in testing where they have actually burned through the tube when they have gone around with the laser, and then there is a question of how well you can reinspect it after you have, for example, a weld overlay. What does that show up as when you put the probe back through and so forth.

Next slide, please.

Free span cracking -- this is where one sees actually axial cracks -- in the free span, not in the vicinity of a tube support plate. Historically we have seen this at Palo Verde in what is called the arc region, which is actually the name of a region high in the tube sheet. It is the outer part of the steam generator, or you might want to think of it as if the tubes are in an arc, in a circle, this is the outer region.

Then McGuire have seen it -- which were cold leg burnishing marks on the tubes. It was observed at ANO-2 in the Fall of '95, last year. They are still looking at the root cause. We haven't heard yet. They have seen it. It is in a different region than the Palo Verde cracks. However, I think for ANO-2 deposits may be a factor.

What is of concern about axial free span cracking is that if -- because if you look at the stresses involved a free span crack in the axial direction that is not constrained, say, by a tube support plate, will burst at a lower pressure than in, say, an equivalent type of circumferential crack and so these would be a real vulnerability compared to other types of cracks.

COMMISSIONER ROGERS: Have you seen those in any of the once-through vertical steam generators, axial cracks?

MR. SHERON: I'm not aware of any free span axial cracks in B&W steam generators at this point.

MR. STROSNIDER: I am getting word from my staff that --

MR. SHERON: Sorry about that. Don't want to mislead you. We'll dig up some more information on that.

COMMISSIONER ROGERS: Yes. It would be interesting to know whether there is any difference there of the once-through vertical steam generators with respect to this axial --

MR. SHERON: Well, in general, the once-through steam generators seem to perform much better in terms of having fewer degradations and one of the reasons I understand is they have stress relieved the entire generator, okay? It was heat treated, so there's none of the residual stresses at these expansions.

Next slide, please.

One thing I do want to point out is while the tech specs at most plants, which were developed maybe back in the '70s, called for plugging when one exceeds a 40 percent through-wall. This has not ever prevented the industry from coming in and proposing different tech specs or alternative tech specs.

One of the reasons I think that the industry has not done this is that there was never an incentive to do it. Right now -- in other words, in order to go out and get the data necessary to properly characterize cracks, get growth rates, et cetera, to pull tubes out of steam generators is a very, very expensive thing to do.

The industry I'm sure from a cost benefit standpoint would say it wasn't worth it at the time, it was easier for me to plug the few tubes that I happened to find.

Now that they are seeing widespread degradation, which is requiring substantial plugging, which could even impact the economic viability of a plant, there is much more incentive I think to get the appropriate data to develop alternative repair criteria. I wanted to point out we have never prevented the industry from proposing it. I just don't think there has been an incentive until recently.

Some of the implications of this, recent inspections have identified many more indications than were anticipated. What we are seeing is that when a plant now may go in and find a few indications on one outage, they'll go in the next outage and maybe find tens or maybe a couple hundred and then the next outage or two they are going to see thousands. So what you are really seeing is that this is a time-dependent phenomena, and it is as they go out in time they are moving the distribution -- you know, they are catching up with it.

MR. RUSSELL: One important safety aspect of that. While there is a distribution we are controlled by the tails of a distribution. That is, a few tubes that have significant cracking that might be a tube that you could have a spontaneous tube rupture at would be of concern or having just a few tubes crack, and so what Brian is describing where you typically see a few tubes that have crack-like indications on one outage, on the next outage you might see tens, the next outage maybe up to a hundred. We are now seeing some cases where we are finding a few thousand with crack-like indications.

This is more than just a change in technology.

Corrosion is going on and it may have some time lag between when the chemistry, the conditions occur, et cetera. There may be some incubation period. There is some type of normal distribution associated with it and even some of these repair reliefs where we may provide some relief may only give relief for a cycle or two until more tubes catch up and you may have to then repair additional tubes, and so this issue is one until they understand the phenomena and what is causing it, it really is going to be one where it's just a period of time.

The issue that is very important is to make sure that the inspections that are done, that they carefully review them. These are very dependent upon human performance to look at these figures. They are done in an intense period of time. That is, when they are in an outage they want to review 10,000-15,000 tubes' worth of data, looking at the data with analysts -- two people checking it.

The human factors aspects of how they do these, with concerns for fatigue, et cetera, missing indications -- our guidelines and our tech specs establish when a repair is necessary. If they don't do a quality job, if they miss indications, if they leave tubes in service that should have been repaired, our requirements are performance-based. That is, tubes that don't meet the criteria are to be removed from service. If they are left in service and they operate with them, then they are in violation of the technical requirements.

We have not in the past taken enforcement for these. As a result, at Maine Yankee we put people on notice that we will be in the future. We have now started to take enforcement where people have missed prior indications and continued to operate.

CHAIRMAN JACKSON: Let me ask you two questions. One is technical and one has to do with what you just mentioned about enforcement.

I learned and saw in action that some licensees have a remote analysis and I guess including using the plus-point probe, which is the more recent type of probe. Is that an accelerating phenomenon, that more are going to that, and what are the implications of it relative to the issues you raised?

MR. RUSSELL: You can collect the signals on-site, digitize them and send them basically to wherever you wish to do the analysis. You can use computer screening techniques. You can do mappings to try and visually display what the phenomena looks like, but you are also typically back to looking at Lissajous figures, trying to decide what is a signal and what is noise and what is not, and these are difficult.

So it also relates to growth rates, and if you look at one outage to the next and you map a particular indication of what you saw this time the next time, you find that there is a distribution associated with that and you will see some that appear to have negative growth rates and others that have very high growth rates.

We want to make sure that cracks are removed from services based upon what you are projecting the growth rate is so that you don't have a flaw that grows to the point where you could have a corrosion tube rupture.

CHAIRMAN JACKSON: I guess what I am really trying to get it as whether or not these off-line analyses, remote analyses, there is no gain necessarily one way or the other as opposed to the onsite?

MR. RUSSELL: No. In fact, it may be that where they send it that they are better set up to perform the analyses there than they would be onsite. Electronic information exchange in steam generator inspection is here and it's a reality today.

CHAIRMAN JACKSON: Okay.

MR. RUSSELL: It's no longer just keeping a magnetic tape of what your eddy current signals were and then sitting and re-looking at them. They are becoming quite sophisticated.

CHAIRMAN JACKSON: Now you mentioned enforcement in steam generator tube integrity space. I mean this is just a question of using existing, our existing regulatory base and being more vigorous about it, or is there any change you are going to be proposing or considering in that regard?

MR. RUSSELL: We did that with the Generic Letter that we issued after Maine Yankee -- to put people on notice that they are in fact responsible and we had some concerns that some licensees may not be following current industry recommendations as it relates to conduct of inspections.

We don't specify what particular inspection to perform. We require that they detect flaws and, once detected, if they are greater than a certain size to repair them.

I don't wish to -- if someone were to have a flaw and they hadn't done an adequate job in looking at it and it were to rupture, the review after the fact if you will look at the prior records, that is not the time to discover it. You want them to review the records, identify the defect and take corrective action for it.

We gave them an opportunity with the Generic Letter and said go back and relook at your records. Make sure that you are not outside of your tech specs as it relates to operability, that you have not in fact operated with defects left in service.

Some licensees did that and identified that they had some cases where they missed some indications. I have concern that there may be some facilities that are still in that category and we are pursuing that based upon some information that we received from EPRI last week that indicates that there may be a few plants that are continuing to operate where they may not be in conformance with their tech specs. We are following up on those plants on an individual basis.

CHAIRMAN JACKSON: So when you get into enforcement space, it has to do with the plant's knowingly operating outside of their tech specs, as opposed to missing something because of --

MR. RUSSELL: No.

CHAIRMAN JACKSON: I am trying to understand where the enforcement issue comes in.

MR. THADANI: I think one issue needs to be made a little bit clearer.

Clearly Appendix B calls for appropriate root cause and corrective action if you find a problem but here the issue on Maine Yankee when we issued the Generic Letter was once they had a significant problem and they went back and looked at prior data, they realized that they may have made a mistake in some cases, so that was not knowingly leaving out some information.

But now that we have that information that those kinds of problems may have occurred other places, we wanted to make sure that the whole industry was basically put on notice. In the Generic Letter we identified this issue and our expectation from that Generic Letter was that the industry would go back, look at prior inspection data to see if they had some indications that they may have overlooked.

CHAIRMAN JACKSON: So the point is it's going forward from here.

MR. THADANI: Right. Exactly.

CHAIRMAN JACKSON: All right.

MR. STROSNIDER: Ashok, I might add something on what we are doing programmatically. In fact, we had a task group made up of regional people and some of my staff which have developed an enforcement guidance memorandum with assistance from the Office of Enforcement.

That is out for comment in the regions right now, and we expect to issue that shortly.

One of the things it does, one it forces us to do is decide what cases would merit enforcement and which wouldn't, and in fact the enforcement guidance memorandum has case studies and that sort of thing in it so that we decide what is appropriate and what's not appropriate.

It goes out to the industry when it is issued so we should have that out soon.

The other thing is in the development of the performance based rule. We are trying to be very conscious of the fact that we want to build enforceability into that rule because that would be working with a different framework than what we are currently working with.

CHAIRMAN JACKSON: Okay.

MR. STROSNIDER: Those are some of the things that are going on.

COMMISSIONER ROGERS: Do you have much information on how successful a licensee might be in re-analyzing those earlier probe results? I mean in Maine they had the early results but then they had the plus-point probe and then they could look and see -- aha, now, you know, knowing that there is a flaw there now with the better probe I can see that there is a little bend and a wiggle on a wiggle that maybe should have given me some suggestion.

MR. STROSNIDER: I would suggest that hindsight is almost 20/20 -- not quite. There are some indications obviously which were just too small to be detected and grew, but in many cases they are going back and seeing that they could pull them out using improved procedures or with increased sensitivity because they know there is something there.

MR. SHERON: One thing they did use at Maine was the thing called a terrain plot, which they did not use previously, and this makes it much clearer for the analyst. Here is an example -- if I could have backup slide number 9, that may help.

This will give you an idea of what an analyst has to see and use.

What you see at the top -- this is I think from a plus-point coil, so you are seeing the two orientations of the coils at the top. Those are the Lissajous figures that the analyst would see. Below is what is called a terrain plot and this is for a crack which is a circumferential -- this is a machined in crack which has two components, two crack components.

You can see which one is easier to distinguish from a terrain plot versus a Lissajous figure, what you are dealing with.

MR. RUSSELL: The issue that I see from a policy standpoint, if the company is performing analysis and they are using gains which are not sufficient to detect the cracking, if they are not doing a high quality inspection, that is more or less a head-in-the-sand type of an approach. That is the type of case that I want to take to Enforcement.

If, on the other hand, there is an inspection excursion, I don't wish them to be penalized because they have used a more sophisticated probe provided once they find the problem, they deal with it at that time. We are seeing some instances, though, where after you have identified the crack in the current inspection, and you go back and you look at it, and you see, well, that crack has been there all along -- it is not growing that rapidly and so you had a condition that was outside the tech specs. We need them to be reported. We may or may not take enforcement action but we need to understand whether these things are growing more slowly, whether they are growing more rapidly, to gather information, and there are explicit reporting requirements.

The fact that the plant shut down at the time that you do the inspection and therefore the generator is not required to be operable does not relieve the company of reporting if they previously operated at power outside of their tech specs, so that is an issue that we are currently dealing with.

MR. SHERON: Just to continue, some of the implications of going into these inspection transients is when they are not anticipated -- one is that there is sometimes nonavailability of repair materials, for example sleeves and the equipment necessary to go into the generators and do the sleeving.

If there is only a limited number of vendors and everybody is in a Spring or a Fall outage, these vendors may be contracted elsewhere and doing work elsewhere so to try and get the equipment and everything moved from one site to another usually can put delays in terms of the restart schedule, which means that the outages sometimes go well beyond their planning horizon.

Then also it may require a mid-cycle outage which was not really planned or scheduled. For example, with Braidwood, they could not really justify going beyond five months of operation before they would have to shut down. This would have brought them down sometime around the beginning of June, which really kind of gave them some grief because that is the middle of their peak season,

They came in with the Byron tube pull data. They pulled 10 tubes out of the Byron plant and made a technical argument why they believed that Braidwood could run for at least nine months and get them through the summer, to September. We are evaluating that right now. I think their analysis looks pretty good, however we have to complete the review, but this is just an example of the kind of problems that occur when one goes in and finds this widespread degradation that was not planned on.

Next slide, please.

The cost of this, as I said before, the industry is focusing right now on developing alternative repair criteria. The Generic Letter 9505 was issued. This allowed the voltage based repair for tubes that are in a Westinghouse generator which have the drilled hole tube support plates, and what it does is it allows cracks, axial cracks, to remain in service if they are within the confines of the tube support plate and they meet certain voltage limits from the eddy current probes.

The reason we can do this is we have now a database which correlates the voltage from the eddy current probe to a burst pressure. One can show that if the voltages remain below a certain value that the structural integrity is maintained.

One of the problems is that when we look at these alternative repair methods it takes a lot of Staff resources to look at a specific one and if everybody is coming in with their own little glitch for their plant we basically run out of resources to review them because everybody wants it done while the generator is down and they are in an outage and the like, and it is usually everything happens in the Spring and in the Fall.

Next slide, please.

I just talked about Generic Letter 95-05. We also went a step further for Byron and Braidwood. They had requested going to higher voltages for the ODSEC and the tube support plates and to justify that they proposed locking the tube support plates in place by expanding certain tubes in the generator above and blow the tube support plates so the support plates physically could not move.

The concern was in a steam line break, the differential pressure loads across the tube support plates would flex them which would allow them to move and expose these cracks, these axial cracks, that were normally within the confine of the tube support plate. The concern was if these tube support plates flexed and then did not return to their original position and then one had an overpressure event between the primary and secondary, you would burst the tubes. So, by locking the tube support plates, this keeps the tube support -- this keeps the cracked region within the tube support plate at all times.

COMMISSIONER ROGERS: Doesn't this introduce a constraint, you know, overconstrained system problem here with respect to thermal expansion and things like --

MR. SHERON: Well, they were -- yes, yes, that was extensively looked at. The stresses that would be induced by this and it was all found acceptable.

MR. RUSSELL: It is also only being done on tubes that are plugged. We are not creating stress rises on tubes that are being rolled to lock the support plate in service or tubes that are removed from service. So they are just being used as tie rods, essentially, not as heat transfer media.

MR. SHERON: Several licensees have indicated the desire to leave certain cracks in service, however we have told them that they need to provide a database to substantiate this. None have really been able to do that so far. Basically what they can tell us is that they can size these cracks and they understand the growth rates and, to do that, you need a database. EPRI is actively working right now to try and develop such a database and correlations and the like.

We just recently had a workshop on steam generator tube integrity. We discussed the regulatory criteria, industry practices. This was held in Charlotte, North Carolina, where the EPRI NDE center is. And, as Jack said, we discussed enforcement guidance and this was -- this workshop was attended by all of the regions, the inspectors as well as their supervisors that are responsible for the steam generator area.

We had representatives, I believe, Chairman, your staff was represented, the EDO staff, AEOD and the ACRS also had representation at the workshop. There were about 40 people there.

MR. THADANI: That was Office of Research as well.

MR. SHERON: I'm sorry, Office of Research as well. They gave presentations on the research program.

Ashok has already told you about the steam generator rulemaking. I don't -- for the sake of time, I think I can skip on that.

CHAIRMAN JACKSON: Well, before you skip, when you are talking about performance criteria, performance-based?

MR. SHERON: Yes.

CHAIRMAN JACKSON: And this goes back to some of the earlier discussions. How dependent on that is that on qualified, whatever that means, NDE techniques?

MR. SHERON: That is part of -- yes. In other words, it is a combination, okay, of making sure that one uses qualified methods when one applies it to meet the criteria.

CHAIRMAN JACKSON: And so that is going to be included in --

MR. SHERON: That will be basically, I believe, in the reg guides. Is that correct?

MR. STROSNIDER: Yes. The need for reliable NDE methods is emphasized in the words of the rule but the regulatory guide also gives a lot of detail on how to qualify methods.

Again, we are not trying to be performance-based, so you can qualify any method you want. But you have to have certain statistics with real defects and that sort of thing.

It is also possible, however, to use, and since you are testing your tube pools where you don't have a qualified method, to look at the end of cycle and say, we still have margin here. And that is a lot of what is going on today and, unfortunately, until the industry can build up a large enough database or qualify inspection methods, that may be something that has to continue.

CHAIRMAN JACKSON: So what you are saying is that your reg guide will talk about how to qualify inspection methods?

MR. RUSSELL: Exactly, yes.

MR. SHERON: And the industry is developing their own guidance document which we are working with them, we are reviewing it. It is hoped that it will be found acceptable such that perhaps we could reference it in the reg guide as an acceptable guide.

COMMISSIONER ROGERS: The emphasis there is on the methods that have to be used to qualify the NDE technique rather than specifying the NDE technique themselves.

MR. RUSSELL: That's correct. The hierarchy would be the rule would establish the objectives, the structural integrity criteria, et cetera, and require inspection. The regulatory guide would identify how you qualify so that a vendor could qualify his particular probes or could be done by a utility.

We would expect the reviews against that regulatory guide could take the form of topical reports. And so, as a new type of degradation is identified, you may come up with a new inspection technique to look for that degradation and we see the two being done together. But with the systematic process very similar to the process we used for Westinghouse for outside diameter stress crossing cracking which we have now gone out with the generic letter and approved.

So we would like to take and institutionalize that process and do it through rulemaking.

COMMISSIONER ROGERS: It is very important that we not lock the technology into an archaic system.

MR. RUSSELL: We would also like to encourage improvements in NDE techniques so that where you improve the capability and sizing and characterizing a flaw, that would allow you to potentially leave a flaw in service for a longer period of time before it gets to the point where it must be repaired to ensure structural integrity.

CHAIRMAN JACKSON: Isn't that somewhat also true in terms of leakage monitoring? I mean, isn't there some variability in the industry in terms of how that is done?

MR. RUSSELL: Yes.

CHAIRMAN JACKSON: And so you are going to kind of try to treat this in an analogous --

MR. THADANI: Yes. Leakage monitoring is a very important part of this activity as well. You are quite correct, that a variety of methods are used today. Some of them are much more effective than others.

MR. RUSSELL: It is important both prior to an event and it is also important to assist the operators in responding to an event to identify the faulty generator because it makes a difference as to what you do in your emergency procedures as to which generator actually has the fault or the leakage.

MR. SHERON: I think again for the sake of time, I will skip to slide 21.

[Slide.]

MR. SHERON: Once we have the draft rule and it has gone through the internal review in the CRGR process, we would issue it for public comment and then, which is kind of a standard procedure, we would then take the public comments, incorporate them as appropriate. We would go back through CRGR and then issue the final rule.

I do want to point out that one of the key aspects of the rule that we were just talking about in terms of specifying, for example, the statistics needed, the database, et cetera, it is not clear that even if we did have the rule in place today that there would be any great additional benefit that would be seen. The reason is that one wants to use it for these other forms of degradation that we are seeing and to develop alternative methods.

The biggest one right now that is of concern is circumferential cracks. The industry is not yet there in terms of having a database and a correlatable method, I guess, for predicting circumferential crack sizes and growth rates. So while, if we did have the rule in place it would certainly provide the framework against which we would expect such correlations and databases to be developed, they are still not there yet.

CHAIRMAN JACKSON: Given that, where does that leave us in the space having to do with alternative repair criteria?

MR. SHERON: Well, right now, the only alternative repair criteria that is approved would be for the voltage based, for the Westinghouse steam generators. We are also on the verge of, I think, approving for like Kewaunee, the sleeves. Remember, I talked about the cracking of the parent tubes?

MR. STROSNIDER: I think the current regulatory framework allows for licensees to propose alternate repair criteria to be reviewed and approved and typically require an amendment to the technical specifications. The idea of the rule is that the industry would be able to do that on their own within the framework of this rule as long as they satisfy the performance criteria. All right, so from the regulatory process point of view there is a difference.

I think the point that Brian wanted to make is that there is no immediate solution to the problems. It still requires developing the same sort of database and the same sort of reliability in the NDE methods before you can go implement it.

The challenge we have is, in the framework of the rule, drawing a box around what the industry can do on their own, such that we are comfortable with it and not making it prescriptive. So you will see things like, if you want to use a correlation of some NDE parameter versus burst pressure, in order to demonstrate that it is correlation, it has to meet some statistical test of the right P factor. Again, you have to consider uncertainties in the correlation parameters. That is the sort of guidance we are given in the reg guide. We are trying to put boundaries on it such that they would be able to go do those things and once they have an adequate database that satisfies that they could implement it.

But in the current regulatory framework people can propose and we can review and approve ultimate criteria.

MR. SHERON: In fact, it is the case-by-case review that is really consuming resources right now.

This would take the staff out of the critical path for implementing this. Once the industry has -- as Jack said, once they have done their homework and developed the stuff in accordance with the criteria, they could implement it and then we would follow up with inspection, okay? But we would not be on a critical path for them to use it.

CHAIRMAN JACKSON: But my understanding is from your second bullet that, in fact, there is a lead lag time here in terms of the techniques and the databases being in place to --

MR. STROSNIDER: Most definitely and I think it creates somewhat of a dilemma for the industry and everyone else. Typically what you see is, in the advances in any current method, the detection sensitivity is achieved before the ability to size, to size the defects. So when you try to develop criteria for leaving defects in service it is very difficult and, at this point, most of them are being taken out of service because they don't have a database or a qualified method.

MR. RUSSELL: Let me illustrate with one other example. When we were doing the outside diameter stress corrosion cracking and you are looking at axial cracks within a support plate, if you pulled a tube, you might get three or four intersections and you might be able to see several axial cracks within that one-inch space because they would be radially spaced around it, so you could pull one tube and you could get quite a bit of data.

If, on the other hand, you are only looking at one location and it is a relative narrow roll transition at the top of the support plate, you may spend a half a million dollars to pull one tube and get one data point. And so the cost of generating the data and having different generators that you use the data, et cetera, and filling in this database is not insignificant. Just the setup alone to pull the tube. So if it is a rolled tube, it is not as easy to drill the support plate, pull the tube out and not damage it in pulling it.

So there are a number of issues that make the circumferential cracking problem harder and more expensive to gather sufficient data to justify leaving them in and that is one of the things the industry is saying now. And so when they are in a critical path outage, if they have got a short outage planned, they don't want to take time to go in and pull tubes to support an industry database. They may choose to just repair their tubes and go on and, well, the next guy will pull the tubes. We are now starting to see a change where licensees are starting to pull a few more tubes and develop the database to support EPRI coming in with some correlations. Unfortunately, the early results don't show good correlation between sizing and signals.

CHAIRMAN JACKSON: Let me ask two questions. Tell me a little more about your schedule for the rulemaking and you talked about the reg guide. My assumption is that your plan is to have that track with the rule itself?

MR. THADANI: Absolutely, yes.

CHAIRMAN JACKSON: Okay, and what -- you talk about enforcement guidance accompanying. What about inspection guidance, since then we are over to a big part of our monitoring the implementation has to do with our inspection but you say that but I don't hear inspection guidance specifically referenced?

MR. THADANI: No, certainly when we go to CRGR for the review, the more important piece they would want to focus on is going to be actually what is the agency going to do so the inspection guidance has to be part of that. We have to lay out what we are going to do as well.

So, but the stuff we must get out because there is a lot of time involved is proposed rule and proposed regulatory guide for public comment period.

CHAIRMAN JACKSON: What is your schedule for this?

MR. THADANI: We are currently assessing the impact on the schedule. You have indicated in your tracking issues list that this is scheduled in September but, quite frankly --

CHAIRMAN JACKSON: You may not be ready?

MR. THADANI: That's right. That's right. And we need to really lay out a clear basis as to what we can achieve, what we cannot achieve.

Now, I, again as Bill was saying earlier, we want to get this rule out as early as we can.

CHAIRMAN JACKSON: Right, but you have to do it the right way.

MR. THADANI: We want to do it the right way.

CHAIRMAN JACKSON: So let me just say the following. You're right, it is in September but what we need is, because of the importance of it and the need for you to think this through, is for you to come back, come back, but we want a date from you as to when you think you can come back and give us a revised schedule.

MR. THADANI: Absolutely. We are going to be preparing a paper. What we are currently doing is going through each issue, trying to see when information would be available and what would it take to finish up, including the interactions that we have to make sure we have with other sections of the agency and we will be sending you a paper that will lay out all of these issues and --

CHAIRMAN JACKSON: How soon?

MR. THADANI: -- like a basis for the paper.

CHAIRMAN JACKSON: How soon?

MR. THADANI: I think that paper we talked about getting out in May.

CHAIRMAN JACKSON: So this is the new date?

MR. THADANI: To get a paper up to you, that will give you the schedule, right. And because there are some uncertainties --

CHAIRMAN JACKSON: I understand.

MR. THADANI: -- we are trying to get a better understanding of that.

CHAIRMAN JACKSON: The point is I am -- the point is not to force you to do something that is not careful because you have a lot to do in putting it all together. It is a very sensitive issue, important as we have been talking about for the last two hours. So it has to be done right when it is done.

At the same time, it is important to have some sense of how things are going to come along. So this is the bargain. We will leave it as September and put a note about this paper and then when we get that we can move the date appropriately.

MR. RUSSELL: It is also important to recognize if we have another fall like we had last fall, or spring, we end up with a lot of case-by-case activity in kind of a crisis mode --

CHAIRMAN JACKSON: And that impacts your resources.

MR. RUSSELL: -- and that impacts our ability to work on generic issues if we are fighting fires.

CHAIRMAN JACKSON: Absolutely.

MR. RUSSELL: If that occurs, we will just have to keep you informed as to what has happened.

CHAIRMAN JACKSON: But at least you can have a schedule that shows the timeline for the activity that can be ongoing. It is just important because it is something that, as you can imagine --

MR. RUSSELL: I agree.

CHAIRMAN JACKSON: -- the industry is very concerned about and people are concerned about and they come to the Commission about these things.

MR. RUSSELL: Yes.

CHAIRMAN JACKSON: Are there any particular comments that you want to make about the NEA steam generator workshop?

MR. SHERON: Only that I think it was very successful. I think it showed that this is not just a U.S. concern but it is an international one, based on the number of participants and the number of countries that attended and I think the major conclusion sums it all up which, what we have been saying, I think most of the foreign participants agree and that is that we have to get more data in order to develop these alternative methods of allowing tubes to remain in service if they do have a degradation.

We do plan, through NEA, to sponsor these workshops about every two years and I think everybody was enthusiastic and thought that was the appropriate time frame.

So, with that --

MR. RUSSELL: Just a general comment on international activities as it relates to steam generators, this is probably an area where the NRC has benefitted significantly from both multinational and bilateral exchanges, particularly some of the information that we received from the French, we have had teams go over and review that data. This has been going on.

MR. THADANI: And Belgium.

MR. RUSSELL: And Belgium as well. But with other countries.

The NEA activities are very beneficial, I think, because it allows the regulators to get together and understand what are the differences in approach and reasons for them and it has been an exceptionally valuable part of our international exchange because there are more pressurized water reactors operating overseas than there are in the U.S. and many of them are U.S. designs using alloy 600. So the operating experience aspects of it are very important. So it is one that we want to continue to encourage and I think whether it is through vehicles such as

NEA or bilateral, we need to keep in tune with our counterparts overseas as to what they are observing and seeing.

CHAIRMAN JACKSON: I agree with you completely.

Commissioner Rogers, anything further?

COMMISSIONER ROGERS: Well, we've been at it about two hours here. It's been a very good briefing and I think very helpful.

Just one small point and that is that we didn't talk very much about preventative measures, particularly the water chemistry situation. I know it is a matter of considerable interest and concern but I am a bit concerned that once we get into a mode and the industry gets into a mode such as it is now that the big issue is detecting cracks, measuring cracks, being able to deal with some mitigative features of repairing steam generators, the emphasis on the preventative end of things may start to drop away.

It is obviously very important but the focus will be on how do we keep going making repairs and there should be a continuing effort to try to find methods to prevent the formation of these cracks. I didn't hear very much about that, although it is in your briefing --

MR. STROSNIDER: Yes, I would make two comments in that regard. First is that the industry does have extensive programs through EPRI looking at water chemistry and preventive measures. Personally, I think that will continue because they have a large economic incentive. I think that is what will drive them. They don't want a forced outage, they don't want to plug tubes if they can avoid it. And that gets back to water chemistry.

The second comment, and we didn't go into any real detail on it, but in the steam generator rule, we explicitly call out a need for the licensee's program to include preventive measures and in the reg guide we don't specify what the water chemistry needs to be but we specify that there needs to be a water chemistry program and that it needs to identify proper parameters and monitoring systems, et cetera.

So, again, trying to put in a performance-based framework, encourage it. And I think the industry won't lose sight of that because they have a real financial incentive.

MR. THADANI: Right. And I think, in fairness, EPRI and others are doing really first class work in many areas, including we went through the issue of monitoring and instrumentation issue fairly quickly here. But EPRI has sent out guidelines to the industry which are fairly -- fairly tight including an evaluation of various monitoring systems and their effectiveness and so on so they are actually -- I think in many areas they are being proactive, at least now.

CHAIRMAN JACKSON: Commissioner Dicus.

COMMISSIONER DICUS: Just a couple comments.

Certainly it has been extremely helpful briefing to me. My knowledge on steam generator tubes has been rather limited and fairly specific to implications in accident scenarios and previous responsibilities, so I thank you very much. It was very helpful. The exhibits were good, too.

CHAIRMAN JACKSON: I want to thank you for what has been a very informative and complete briefing. I just encourage you to continue proactively in as timely a manner as you can and we look forward to getting this paper with your plans because I think, you know, I was looking back at some SECYs that predated me. It is an area where the ground is shifting as we speak. At the same time, we want to come to some concurrence on this. Mr. Russell said some of the basic regulatory issues, as soon as we can and then a lot of the rest is going to depend -- and I encourage you to continue working with industry.

I mean, there are two pieces to it. One has to do with the regulatory framework obviously and that is what our concern is but, given the safety and the engineering and the financial significance of what we have been talking about, I mean it is a challenge for the industry and one that I would hope that they would redouble their efforts to take up.

So, again, I guess we can finish looking at Exhibits A through -- I counted them -- J.

Thank you. We are adjourned.

[Whereupon, at 11:52 a.m., the briefing was concluded.]

CERTIFICATE

This is to certify that the attached description of a meeting of the U.S. Nuclear Regulatory Commission entitled:

TITLE OF MEETING: BRIEFING BY STAFF ON STEAM GENERATOR ISSUES - PUBLIC MEETING

PLACE OF MEETING: Rockville, Maryland

DATE OF MEETING: Tuesday, February 27, 1996

was held as herein appears, is a true and accurate record of the meeting, and that this is the original transcript thereof taken stenographically by me, thereafter reduced to typewriting by me or under the direction of the court reporting company

Transcriber: Rosalie Heroshon

Reporter: Michael Paulus

Steam Generator Tube Integrity

February 27, 1996

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for Technical Review
Office of Nuclear Reactor Regulation**

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Outline

- Importance of Steam Generator Tube Integrity
- Approach for Addressing Tube Integrity
- Tube Inspections
- Examples
- Implications
- Short Term Regulatory Actions
- Steam Generator Rulemaking
- NEA Steam Generator Workshop

Importance of Steam Generator Tube Integrity

- Steam generator (SG) tubes constitute a significant portion of the reactor coolant pressure boundary (RCPB)

- Loss of SG tube integrity has important safety implications:

  - Small LOCA bypassing containment

  - Additional failures of mitigating systems could lead to direct release of significant radioactive fission products

Importance of Steam Generator Tube Integrity (cont'd)

Regulatory Requirements

- Design and Operating Requirements
  - General Design Criteria; 10 CFR Part 100 Guideline Values
  - Technical Specifications:
    - Inspection and Repair Criteria; Leakage Limits; Activity Limits
- Present technical specifications (TS) developed about 20 years ago when prevalent forms of degradation were wall thinning and wastage
- TSs do not reflect either current degradation modes or inspection technology and are inappropriate for some forms of degradation

Importance of Steam Generator Tube Integrity (cont'd)

- Previous studies (NUREG-0844)
  - Acceptable level of risk
    - Spontaneous tube rupture
    - Consequential tube failure
- New degradation modes
- If a severe accident produces conditions under which degraded tubes can fail, significant radiological releases may occur

Approach for Addressing Tube Integrity

- Staff is developing a risk informed/performance based approach to address steam generator tube integrity
- Safety goals subsidiary objectives
  - Core damage frequency
  - Containment performance (potential for containment bypass)
- Key elements
  - Frequency of spontaneous tube ruptures
  - Probability of tube rupture
    - Postulated accidents (e.g., steamline break)
    - High pressure/temperature severe accident sequences

Approach for Addressing Tube Integrity (cont'd)

- Need better understanding of safety significance of high temperature challenges
  - Frequency of relevant sequences (IPEs, PRAs, design factors)
  - Thermal hydraulic analyses to develop pressure/temperature profiles
  - Material engineering (RCPB response)
  - Flawed tube failure probability
- Outcome will ensure compliance with General Design Criteria and defense-in-depth consistent with desired level of safety

Approach for Addressing Tube Integrity (cont'd)

- Industry and the NRC are addressing tube integrity
  - Industry is developing degradation specific management proposals for ensuring tube integrity
  - Staff is developing a rule and associated regulatory guide
  - Staff and industry are interacting on tube integrity issues
    - Industry hesitant on incorporating severe accident issues in rule and regulatory guide

Tube Inspections

- Inspection technology has continually been improving
  - Improved technology (probes, software)
  - Improved data analysis criteria
- Inspections using improved technology generally result in detecting degradation earlier
  - Unless structural significance of these indications can be quantified, licensees must plug or repair all indications per depth-based repair criteria
- Recent inspection results indicate that stress corrosion cracking continues to be dominant degradation mechanism

Examples

- Circumferential cracking
  - Several large circumferential indications detected this fall
    - ANO-2, Braidwood, Sequoyah, Salem
    - Tubes with circumferential indications are plugged or repaired
  - Mid-cycle inspections may be necessary

Examples (cont'd)

- Dent inspections

  - Axial primary water stress corrosion cracking (PWSCC) and/or circumferential cracking has been found at dented intersections at a number of plants

    - Diablo Canyon, Sequoyah, Salem

  - Prior to this fall, North Anna was only plant which had experienced this phenomenon recently

  - Axial PWSCC found at intersections with small magnitude dent signals

Examples (cont'd)

- Sleeve joint cracking

  - As a result of GL 95-03 and recent industry experience, industry has been performing more extensive inspections (plus-point, Cecco)

  - Indications being found at B&W kinetic sleeves and Westinghouse hybrid expansion joint (HEJ) sleeves

  - Long term integrity of sleeved tubes continues to be an issue

  - Alternate repair criteria are being proposed for Westinghouse HEJ sleeves

    - Kewaunee, Point Beach, Cook

Examples (cont'd)

- Free span cracking
  - Historically observed at Palo Verde (arc region) and McGuire (cold leg manufacturing burnishing marks)
  - Observed at ANO-2 in fall 1995
    - Root cause is still being investigated
    - In different region than Palo Verde cracks; however, deposits are believed to be a contributing factor
  - Point Beach and Farley have also detected a limited number of free span indications

Implications

- Option to propose alternate tube repair criteria exists

- Recent inspections have identified many more indications than were anticipated. Some utilities were not prepared for large tube repair campaigns

  - Unavailability of repair material/equipment

  - Outages extended well beyond planning schedule

  - Mid-cycle outages may be necessary

Implications (cont'd)

- Recent trends have resulted in industry focusing on development of alternate repair criteria
  - Outside diameter stress corrosion cracking at tube support plates (e.g., Generic Letter 95-05)
  - Supporting data base is essential
- Expenditure of staff and industry resources to assess tube integrity and to develop alternate repair criteria
  - Time-frame for reviews is sometimes very limited

Short Term Regulatory Actions

- Generic Letter 95-05 permits axial cracks to remain in service provided
  - Cracks located within region where the tube passes through the tube support plates (TSPs)
  - Eddy current voltages remain below specified values
  - Conditional probability of tube burst remains below a specified value during next operating cycle
  - Other structural and leakage integrity concerns are satisfied
- Staff recently approved a modification to GL 95-05 which permits higher eddy current voltage indications to remain in service
  - Involves locking of the TSPs in place

Short Term Regulatory Actions (cont'd)

- Generic Letter 95-03
  - Highlighted significance of using appropriate inspection technology
- Several licensees have indicated desire to justify leaving certain circumferential cracks in service
  - Staff has indicated that it will not entertain such proposals unless adequate data base exists (i.e., an adequate technical basis)
- NRC workshop on steam generator tube integrity
  - Regulatory criteria
  - Industry practice
  - Inspection and enforcement guidance

Steam Generator Rulemaking

- Staff is developing risk informed/performance-based rule to address numerous shortcomings with current regulatory framework. Rule to require:

  - Development/implementation of a SG program

  - Monitoring tube condition against accepted performance criteria to ensure tubes can perform safety functions

  - Corrective action when performance criteria exceeded

- Rule to contain high level performance criteria on

  - Structural integrity of tubes

  - Primary-to-secondary leakage monitoring

  - Accident dose consequence evaluations

Steam Generator Rulemaking (cont'd)

- Accompanying Regulatory Guide to contain specific guidelines on performance criteria and on meeting performance criteria

  - Condition monitoring assessment - assessing as found tube condition against structural and leakage criteria
  - Operational leakage monitoring, limits, and response
  - Radiological dose assessment

Steam Generator Rulemaking (cont'd)

- Regulatory Guide to contain guidelines on other related areas of the required SG program
  - Severe accident risk assessment (depending upon results of ongoing risk studies)
  - Operational assessment - assessing tube integrity for next operating cycle
  - Preventive measures that should be developed/implemented including secondary water chemistry, loose parts control and measures to mitigate active degradation mechanisms
  - Tube inspection and repair criteria
  - Corrective actions
- Regulatory Guide may reference industry documents

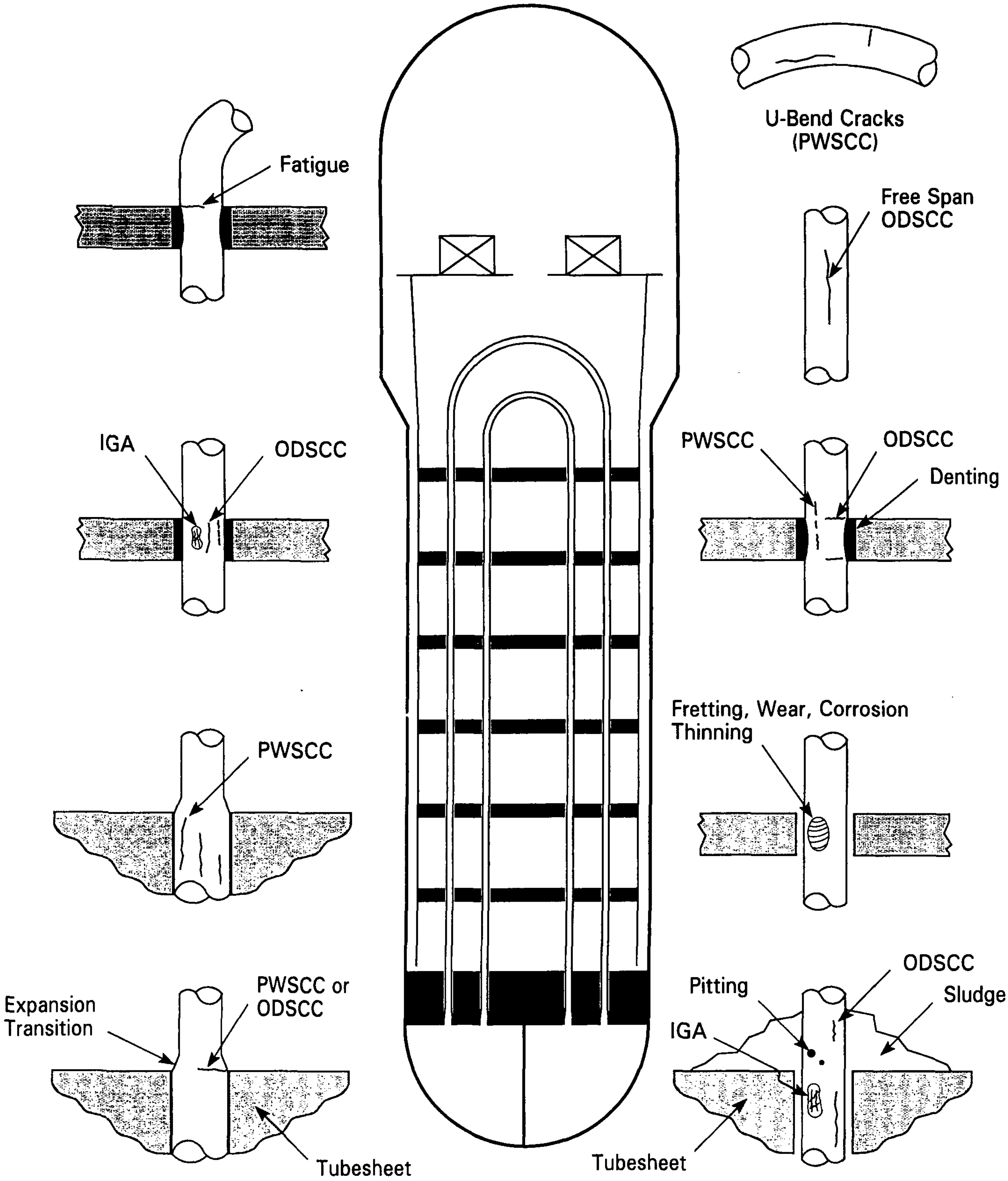
Steam Generator Rulemaking (cont'd)

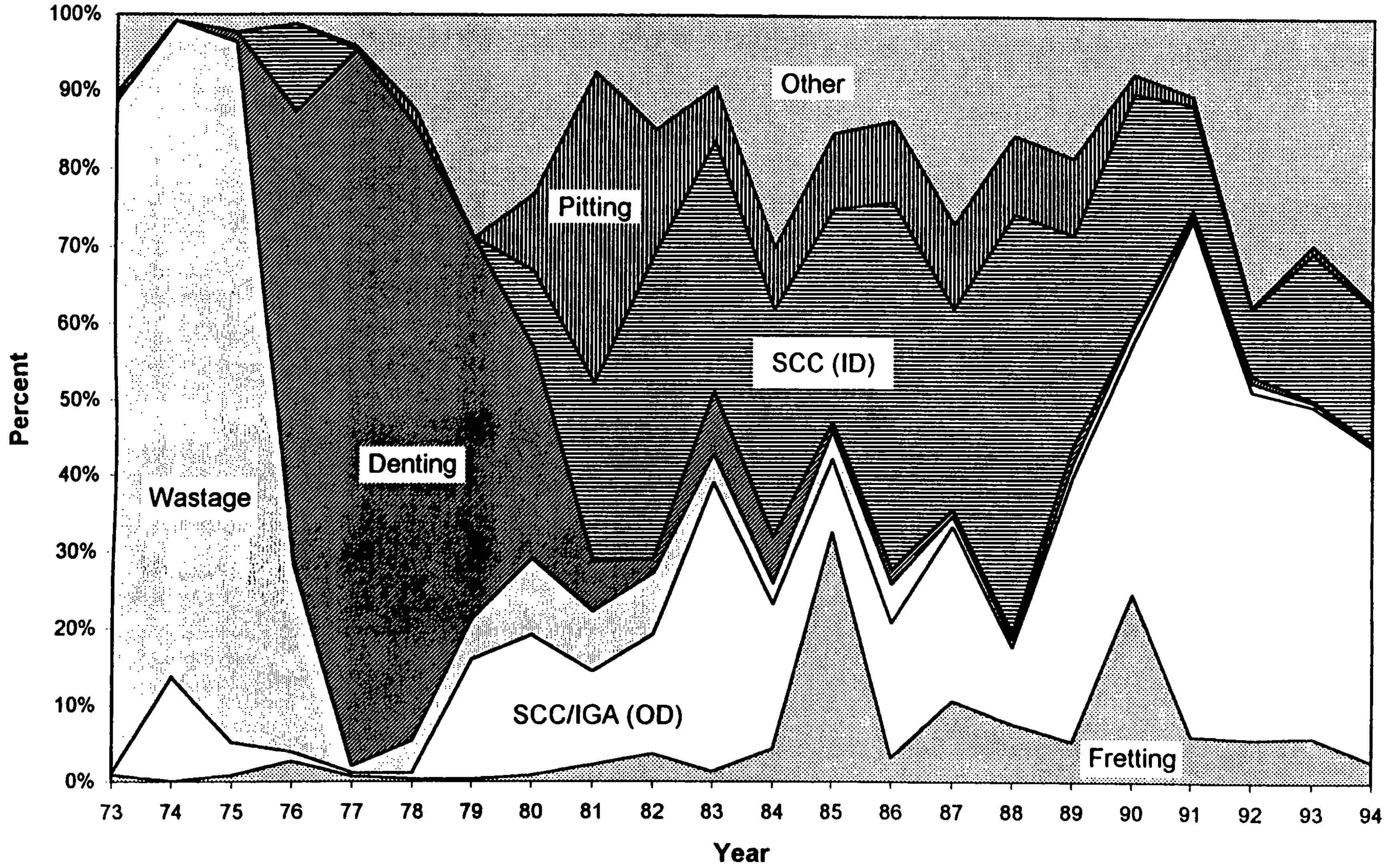
- Schedule for issuance of the draft SG rule for public comment
- Even if the rule were in place today, benefits would be minimal because the industry has not yet developed structural and leakage integrity data bases and qualified NDE techniques for all forms of degradation
- Industry implementation of rule will be monitored through inspection activities
- Accompanying enforcement guidance to be developed

NEA Steam Generator Workshop

- Hosted by NRC/RES in Chicago, Illinois from 30 October to 2 November
- ~100 participants from 15 countries including regulators, utility personnel, vendors, and R&D personnel
- Exchange of information on:
  - Degradation mechanisms
  - Inspection technology
  - Tube integrity evaluations
  - Preventive/corrective measures
  - Operations and risk assessment
- Major conclusion: More data from examination of tubes removed from service are needed
- NEA proposes to sponsor SG workshops approximately every 2 years

EXAMPLES OF SG TUBE DEGRADATION MECHANISMS





United States Causes of Steam Generator Plugging