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UNITED STATES NUCLEAR REGULATORY COMMISSION

IN THE MATTER OF: | DOCKET NO:

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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In the matter of: :

CAROLINA POWER AND LIGHT COMPANY : Docket Nos. 50-400 OL
and NORTH CAROLINA EASTERN MUNICIPAL : 50-401
POWER AGENCY :

(Shearon Harris Nuclear Power Plant, :
Units 1 and 2.) :

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ECU Room,
Ramada Inn, U.S. 1 South
Apex, North Carolina 27502

Tuesday, 16 October 1984

The hearing in the above-entitled matter was convened, pursuant to adjournment, at 9:00 a.m.

BEFORE:

JAMES L. KELLEY, Esq., Chairman,
Atomic Safety and Licensing Board.

DR. JAMES H. CARPENTER, Member.

DR. GLENN O. BRIGHT, Member.

APPEARANCES:

(As heretofore noted.)

WRB/wb

C O N T E N T S

WRB/wb

INSERTS

P R O C E E D I N G S

JUDGE KELLEY: Good morning. My name is James Kelley. I am the lawyer-chairman of this Atomic Safety and Licensing Board panel.

On my right is Judge Glenn Bright. On my left is Judge James Carpenter.

Why don't we begin with the introductions of Counsel and parties around the table.

Do you want to start, Mr. Eddleman?

MR. EDDLEMAN: I am Wells Eddleman, representing myself.

MR. RUNKLE: My name is John Runkle. I represent the Conservation Council of North Carolina.

MS. MOORE: My name is Janice Moore, representing the NRC Staff.

With me is Charles Barth, also representing the NRC Staff.

JUDGE KELLEY: And the gentleman on your right?

MS. MOORE: That is Mr. Marsh, one of the Staff's witnesses.

MR. BAXTER: Appearing on behalf of the Applicant, I am Thomas A. Baxter.

To my left is Samantha Frances Flynn.

To my right is John H. O'Neill, Jr., and to Mr. O'Neill's right is Pamela H. Anderson.

Mrs. Flynn is Associate General Counsel of Carolina Power and Light Company, and the rest of us are with the law firm, Shaw, Pittman, Potts and Trowbridge.

JUDGE KELLEY: Thank you.

This is the second session of the safety phase of the operating license hearings. We have a slightly revised order of contentions.

The Applicants supplied us and the parties this morning with a two-page document entitled "Order of Testimony Presentation - October 16th Hearing," and I will just tick off the contentions themselves.

Joint Contention VII, Part 4, will be first, concerning steam generator tube rupture analysis.

Eddleman 116 on fire protection is next, followed by Eddleman 9 on electrical equipment environmental qualifications, followed by Eddleman 65, containment concrete, followed by Eddleman 41, pipe hanger welding and finally Joint Contention IV on thermal lumenescent dosimeters.

In our prior hearings on environmental issues in the first part of the safety hearing, namely, the management hearing, we have been following more or less conventional procedural groundrules. I will just mention them briefly.

I might note first that the written testimony, the written direct testimony and the exhibits in connection with the testimony has already been filed in advance. Our order of presentation of direct cases will be the Applicants first, the Intervenors, on the contentions where they are going to put on a direct case, and the NRC Staff would be last.

Our order of examination or cross-examination would be as follows. It varies of course, depending on whose case is involved but as an example, on the Applicants' case, the Intervenors would question first, cross-examine first, and the Staff would cross-examine next, followed by questions from the Board, followed by any recross from the Intervenors on new matters raised by either the Staff or the Board, and followed by the Applicants' opportunity for redirect. And there can be some recross/redirect after that in particular situations.

By way of procedural preliminaries, I think the lawyers -- I might just add I think the lawyers have done a good job in the case over the past many months in working things out in advance, and we have not had to do an awful lot of procedural discussion and sparring when we come to these hearing sessions. And that is all to the good.

We have done that here again, as we understand it, so there is not a great deal we need to go over.

I believe the Staff had a word for us on one of their potential witnesses.

Mrs. Moore?

MRS. MOORE: Yes. This matter concerns Joint Contention IV which is the TLD issue.

At the end of the last hearing the Board asked what witnesses would be presenting testimony, and we stated at that time that we did not intend to present the testimony of Dr. Philip Plato, and indeed, in our testimony that we filed, Dr. Plato is not one of our witnesses. However, the Board did express an interest in hearing from Dr. Plato, and we did some investigation and found out that he could be made available if the Board wished it in light of the testimony that they have already received.

But it would necessitate a little bit of a scheduling problem.

Dr. Plato is only available up through November 2nd. He is unavailable in the week of November 6th, which is the now presently scheduled last week of the hearing. And I would like to know the Board's wishes on this matter. If the Board does not wish to have him, we don't intend to offer him as a witness.

JUDGE KELLEY: Well, since we of course are in search of the truth, it is awfully hard to turn down an opportunity to talk to somebody named Plato.

(Laughter.)

I think it is going to be something that my colleagues will primarily determine.

I wonder if as we get through this first contention we might be in a better position to say whether we want to hear from him especially or not.

Can you indicate what his particular expertise would be on this contention, what area?

MRS. MOORE: Well, Dr. Plato was principal author of the document which was referred to by the Board in its order concerning this hearing. The NUREG number right now escapes me, but it is the NUREG that involves the data concerning Harris TLDs. He was one of the people that worked on that document.

The Staff believes that its testimony provides information that the Board needs, but the Board did express an interest and that is why we are raising this matter at this moment, and also to let Dr. Plato know whether he will be required.

JUDGE KELLEY: Excuse me just a minute.

(The Board conferring.)

JUDGE KELLEY: We will try to give you a better indication later today or tomorrow. Is that all right?

MRS. MOORE: That's fine.

JUDGE KELLEY: Thank you.

And I believe that Mr. Runkle indicated in our informal conference up at the bench before we started we did have a pending Freedom of Information Act request from the Intervenors to the NRC, I gather.

Is that right, Mr. Runkle?

MR. RUNKLE: Yes, sir.

JUDGE KELLEY: And that was pending at the time we closed the record on the management contention, but we did explicitly contemplate the possibility that there might be further documentation forthcoming and that we might, if appropriate, reopen to let in some further paper.

Are you going to bring us up to date on the status of that?

MR. RUNKLE: Yes, sir.

In the letter dated September 14th, and it was also put into the Public Document Room up in D. C., were some 52 documents relating to the SALP reports, and these were material that was released. A lot of the stuff was things that had already been entered into the record on the violations, copies of the SALP reports, but some of the analysis behind it and suggestions and memoranda and that kind of thing, and most of it related only to Harris rather than Brunswick and Robinson.

We received on September 25th a listing of that information which would at this time probably be denied, and it contains some 64 documents relating to the SALP reports and Robinson and Brunswick that were described as unreleasable material, and another 20 that were called draft material to be withheld. And the agency is still processing this request.

I would be glad to submit both these lists to the Board just to show what kind of information we requested and what kind is still in the works that we may or may not get.

JUDGE KELLEY: Okay. That's fine.

MR. EDDLEMAN: If I might, I would just like to state for the record that I filed the FOIA request for all these reports on the 3rd of August, and the first response was 14 September, and I think this is outside the statutory deadlines of the NRC's own procedures responding to these things. And I would just like to indicate that we followed them as fast as we can on it when it has been our turn to ask for things. But the response has not been forthcoming in a timely manner.

JUDGE KELLEY: Any comment from the Staff on that?

MR. BARTH: Your Honor, we are aware of both letters. The first letter I sent to everybody in the room here shows the documents that had been released and put in the Public Document Room. And the agency is basically withholding the predecisional documents on the SALPs which is authorized, in our view, under the Freedom of Information Act.

As to the second letter to which Mr. Runkle has alluded, I really don't see any reason to put these things in the record as evidence. They are certainly not relevant to anything so far.

JUDGE KELLEY: I'm not clear I guess on one point now. I thought I understood Mr. Runkle to say that the request was essentially pending and was still being processed, but have some of these documents at least -- has the request been denied as to some of them on the ground that they are predecisional?

MR. BARTH: On approximately 60 to 65 of the documents, your Honor, which basically emanated from the Atlanta Regional Office and are the predecisional documents relating to the SALP from that office.

JUDGE KELLEY: There has been a denial as to those?

MR. BARTH: The denial is not official. Mr. Eddleman was informed what would be denied. The formality of sending a letter from the agency denying has not been done, but he has been informed what documents will be denied, your Honor.

JUDGE KELLEY: So it is technically pending but there is a rather strong signal that has been put out to the effect that there will be a denial. Is that correct?

MR. BARTH: Yes, your Honor, you're correct.

JUDGE KELLEY: Well, putting to one side-- I understand your point, Mr. Eddleman, about timing and we know that the FOIA requires a ten-day turn-around except in certain circumstances, and so on, but from our standpoint as a Board considering an issue, your desire, as I understand it, the desire of the Joint Intervenors was to get in certain of this documentation into the record so it could be considered in relation to our decision on management. Correct?

MR. RUNKLE: Yes, your Honor.

JUDGE KELLEY: So if we are still a good long ways from the filing of proposed findings stage, even though it may be late into the FOI it isn't yet causing us any problem, is it?

MR. EDDLEMAN: It is not causing the Board a problem. It is certainly causing us a problem. I have not actually received, unless it came in yesterday at my office, the written statement that this stuff is probably going to be denied. If Mr. Runkle has it, I haven't got it, and I am the requester, or I'm one of the requesters.

What I'm getting at is that sure, you know, the Board doesn't need it until findings are due. That's certainly true.

JUDGE KELLEY: That's right.

MR. EDDLEMAN: But we need it in order to prepare the findings. And what we are going to have to do -- it's very obvious -- to get anything on Brunswich and Robinson -- and this is the thing that -- I mean anything that has not been released which is just the SALPs themselves, on the others, as I understand it, we're going to have to go through an appeal.

And the last time I filed an appeal it took -- oh, I think about 45 days to get an answer. If you don't like the answer you've got to go to the federal court. I think it is working prejudice to our case to not have the documents in hand. If we have them in hand it may turn out they are not useful to us, and that will be the end of it. Okay?

But to the extent that any of this information may be useful, we are being prejudiced by this stuff not coming forward in a timely manner.

JUDGE KELLEY: So if you got put under a limit within which to file findings you might find yourself in a squeeze. Is that what it comes down to?

MR. EDDLEMAN: Yes, sir.

JUDGE KELLEY: Well, maybe for this morning at least we ought to, you know, register the problem. As I am sure you are aware, the Board's control over this process in any direct way is I think kind of limited in the sense that it's an FOI, you know, and it is up to the Staff. It is not discovery. We can control discovery.

It is discovery in the sense that people use the FOI for discovery. Everybody does. It is a perfectly legitimate thing to do, but the Board does not control it in a direct way. We do control, you know, time for findings and things like that.

I think I understand basically what is going on.

Would it be possible-- I think it would be helpful to us to just -- whatever correspondence you've got on this point, if you'll give us a xerox copy so that this will be something we could look at and get a better handle on what is going on, that would be helpful. And serve anybody who doesn't have a copy also.

MR. RUNKLE: We would be glad to do that. That was our intent. This was just for informational purposes and not to be put into evidence.

JUDGE KELLEY: Surely.

MRS. FLYNN: Mr. Chairman,--

JUDGE KELLEY: Can I make one other point? Well, why don't you go ahead.

MRS. FLYNN: Applicants have two points to make.

First, as we pointed out at the last session, this is entirely beyond the Applicants' control as well, and whether or not the Freedom of Information Act request is granted or denied, and whether Intervenors take an appeal, that should not impede the schedule for proposed findings and conclusions.

If there is a need in the Intervenors' mind to move to reopen the record, that can be done at any time, whether proposed findings are filed or not.

Second. this is something we did not mention at the last time. We thought it was implicit, but I think we should ask for some clarification now and a ruling that in the event that the Intervenors want to move to reopen the record with respect to any documents, those that have already been filed -- those that have already been received by them or any that may be subsequently received, that a time limit be set within which, from the date of receipt, they have an obligation to file such a motion.

JUDGE KELLEY: Maybe so. What don't you let us think about this a little bit.

Let me just add that not only to we have limited control, we don't have any direct control over FOI responses and there can be a problem arise when you have the FOI and its operations in effect controlling litigation.

Somebody says I don't want to do something or other, whether it is filing a motion or filing findings or doing anything, until I get an FOI response. The Board's general reaction is that's between you and the agency, that is not our problem. But not necessarily.

We can take into account the fact that this is a way of getting information.

It seems to me to be premature for us to do anything this morning about this particular problem. We don't have a time for filing findings, for example. But if you would give us the correspondence, we can at least get a firmer handle on it, and we can bear in mind possible impacts of allowing the FOI sort of tail to wag our dog. We don't want that to happen.

Why don't we wait a little bit so I can at least see the correspondence and think about it a little bit.

MRS. FLYNN: All right.

JUDGE KELLEY: I understand your concern and you won't be prejudiced in your opportunity to make a motion. But rather than carry it any further this morning, why don't we let it sit for now, and perhaps we can work out a sort of reasonable way to solve the problem without prejudicing anybody.

MRS. FLYNN: Thank you.

JUDGE KELLEY: Is there anything else that we should discuss this morning before turning to the Contention VII and our first witness?

(No response.)

JUDGE KELLEY: Who is calling--

MR. O'NEILL: Your Honor, if I might make a statement before calling the witness?

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Take 2

Joint Contention 7 was admitted by stipulation at the prehearing conference in March of 1982. As admitted, Joint Contention 7 addressed four issues. One, vibration problems in Model D, Westinghouse steam generators. Secondly, tube corrosion and cracking in AVT water chemistry environment. Third, detection of loose parts. And four, tube failure analyses.

Later, in January 1984, Mr. Edelman proposed contention 180, which related to an SER open item on the operator response time for steam generator tube failure analyses. The Board ruled on March 8, 1984 in a conference call that Edelman Proposed Contention 180 was incorporated into part four of Joint Intervenor Contention 7.

May 16, 1984, Applicant's moved for summary disposition of parts one, two, and three of Joint Intervenor Contention 7. The Staff supported Applicant's motion, and the Board ruled on July 12, 1984 in favor of Applicant's motion and dismissed parts one, two, and three of Joint Intervenor Contention 7.

Applicant's motion for summary disposition was supported by affidavits of Thomas Timmons, William Wilke, Glen Lang, Ellen B. Cutter, and Michael Hitchler, who is our witness here today.

The factual information in his affidavits was not controverted by the Joint Intervenors or Mr. Edelman.

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Applicants and Joint Intervenors entered into an agreement of settlement, dated July 23, 1984, with respect to the issue raised by Proposed Edelman Contention 180 on operator response time. The Board, on July 27, 1984, approved that stipulation of settlement and dismissed and disposed of the issue relating to operator response time.

Thus the only issue before this Board and this proceeding is as set forth in footnote 1, on page 3, of the stipulated agreement of settlement dated July 23, 1984, and that is that Applicants have failed to consider multiple tube ruptures in their steam generator tube rupture analysis.

With that background, Applicants would call Michael J. Hitchler as our first witness.

JUDGE KELLEY: Thank you.

Whereupon,

MICHAEL J. HITCHLER

was called as a witness and, having been first duly sworn, was examined and testified as follows:

DIRECT EXAMINATION

BY MR. O'NEILL:

Q Mr. Hitchler, do you have before you a copy of the written statement that was filed with the Board on August 9, 1984, in response to Joint Intervenor Contention 7(4).

A I do.

Q Will you please identify that statement for the record?

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A It's dated August 9, 1984 and it's Applicant's testimony of Michael J. Hitchler in response to Joint Intervenor's Contention 7, part 4 (Steam Generator Tube Rupture Analysis).

Q Mr. Hitchler, would you please talk into the microphone a little closer? Thank you.

Does that written statement consist of 13 pages of questions and answers, eight tables, a four-page attachment, and a figure A-1?

A It does.

Q Was this testimony and the attachment prepared by you or under your direct supervision?

A It was.

Q Do you have any changes or corrections to make to this written statement at this time?

A I do not.

Q Is this statement true and accurate to the best of your knowledge, information, and belief?

A It is.

Q Mr. Hitchler, did you also prepare an affidavit that was filed with Applicant's motion for summary disposition of Joint Intervenor Contention 7, parts one, two, and three?

A I did.

Q Is there any statement in that affidavit that you wish to clarify at this time?

A Yes. Several numbers were inadvertently switched

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in doing the analysis for the affidavit for summary disposition. Those transpositions have been corrected and are correct in the August 8th submittal of my testimony.

The bottom line numbers, though, do not change, nor do any of my conclusions.

MR. O'NEILL: Mr. Chairman, I would move that the testimony of Michael J. Hitchler, including tables 1 through 8, attachment A, figure A-1 be incorporated into the record as if read and be received into evidence.

JUDGE KELLEY: There is no objection? Staff?

MRS.MOORE: No objection.

JUDGE KELLEY: Motion granted. It'll be bound into the record and the evidence is admitted.

MR. O'NEILL: Thank you, sir.

(The document follows.)

August 9, 1984

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
CAROLINA POWER & LIGHT COMPANY	)	Docket No. 50-400 OL
and NORTH CAROLINA EASTERN	)	
MUNICIPAL POWER AGENCY	)	
	)	
(Shearon Harris Nuclear Power Plant)	)	

APPLICANTS' TESTIMONY OF MICHAEL J. HITCHLER
IN RESPONSE TO JOINT INTERVENORS CONTENTION VII (4)
(STEAM GENERATOR TUBE RUPTURE ANALYSIS)

6 0043

Q.1 Please state your name, address, present occupation and employer.

A.1 My name is MICHAEL JOHN HITCHLER. I am Manager of Plant Risk Analysis with the Nuclear Safety Department of Westinghouse Electric Corporation, P. O. Box 355, Pittsburgh, Pennsylvania 15230.

Q.2 State your educational background and professional work experience.

A.2 I was graduated from Lowell Technological Institute in 1974 with a Bachelor of Science Degree in Nuclear and Mechanical Engineering and from Carnegie-Mellon University in 1978 with a Master of Science Degree in Mechanical Engineering.

I have published five articles in various technical periodicals and have authored or coauthored eight Westinghouse reports which pertained to reactor accident analyses, emergency/abnormal operating instruction development and probabilistic risk analyses.

I joined Westinghouse in June 1975 as an Engineer. I was promoted to Senior Engineer in December 1978. My responsibilities during that time included performing accident analyses for use in licensing documents. I have served as a Westinghouse liaison with the NRC, architect engineers and utilities for issues concerning reactor protection system design requirements. My specific areas of specialization included core and systems response to transients initiated in the primary system, development of methodology for safety analysis of reload cores, and simulation of actual plant transients for computer verification purposes. I also had the lead responsibility for the transfer of the above technology to various utility customers. This responsibility included the structuring of classroom as well as on-the-job training for a number of utility personnel.

In June 1981, I was assigned responsibilities in the risk assessment area. These responsibilities involved the development and implementation of strategic programs to enhance and to apply risk assessment technology for use in nuclear power plant design and licensing. This work included development and quantification of event trees for use by the Westinghouse Owner's Group in reviewing emergency and abnormal operating procedures as part of its response to post TMI issues. I assisted in the development and review of Auxiliary Feedwater System Reliability Studies for three nuclear plants.

In October 1981, I was promoted to the position of Manager, Probabilistic Risk Assessment (PRA) Group. I presently have lead responsibility for a probabilistic risk study of two non-domestic, pre-construction nuclear stations, which includes development of a risk baseline and an assessment of potential design alternatives. I have also worked on three domestic station risk studies, contributing extensively in the following areas: plant and containment event tree construction, systems success criteria for fault tree development, external (seismic, wind, fire, etc.) event analysis and review of the results sections.

I am a member of the American Nuclear Society (ANS) and the American Society of Mechanical Engineers. I served on two ANS Standards committees and contributed to several Atomic Industrial Forum (AIF) and Institute of Electrical and Electronics Engineers (IEEE) committees on development of risk criteria and utilization of PRA approach to licensing.

Q.3 Please elaborate on your professional experience that is directly relevant to the testimony which you are presenting regarding steam generator tube rupture events.

A.3 I have been involved in developing probabilistic models to quantify the frequency of steam generator tube rupture events, and their consequences in terms of core melt frequency and public risk, since 1982. I have directed the performance of PRA analyses of tube rupture events for the Byron, Millstone 3, Sizewell B (British), and PUN (Italian) nuclear power stations.

Q.4 What is the purpose of your testimony?

A.4 The purpose of my testimony is to address the one remaining issue in this proceeding raised by Joint Intervenors Contention VII -- i.e., the allegation that Applicants' steam generator tube rupture analysis found in the Final Safety Analysis Report is inadequate because it fails to consider multiple tube rupture events.

Q.5 Describe the steam generator tube rupture event that is analyzed by Applicants in the Harris Plant Final Safety Analysis Report (FSAR).

A.5 The Harris FSAR contains an analysis of a single double-ended rupture of a steam generator tube, consistent with Section 15.6.3 of the NRC "Standard Review Plan," NUREG-0800, Revision 3.

Q.6 Steam generator tube rupture events are defined as "Condition IV" events in Section 15.0 of the Harris FSAR. What is a Condition IV event?

A.6 "Condition IV" events are defined as faults which are not expected to take place during the lifetime of the plant. In other words, the frequency of these events is judged to be less than once in 40 years, or less than 2.5 x 10^{-2} per year.

Q.7 Is this characterization of a steam generator tube rupture as a Condition IV event consistent with the operating history of Westinghouse pressurized water reactors (PWR)?

A.7 This characterization is consistent with PWR performance in the approximately 233 plant years of experience to date. As I will explain below, based on historical experience alone, the frequency of steam generator tube ruptures is predicted to be no more than once in 45 years of operation.

Q.8 What is the total number of tube years of experience in Westinghouse-design nuclear plants with Inconel steam generator tubes similar to the tubes in the Harris Plant steam generators?

A.8 The total number of tube years of experience in Westinghouse-design plants with Inconel steam generator tubes was determined, based on data through July 1983, as shown in Tables 1 through 6.

These tables cover different categories of plants and set forth plant designation, number of tubes, date of commercial operation, and total calendar years between beginning of commercial operation and July 1983. The data in these tables show a total of over four million tube years of experience since the beginning of commercial operation. For purposes of our analysis here, these data were discounted 10 percent to 3.6 million tube years.

Q.9 How many tube rupture events have actually occurred in Westinghouse-design nuclear plant steam generators?

A.9 Table 7 presents a list of tube rupture events that have occurred in Westinghouse steam generators. All five of these events had flow rates large enough to cause plant trip and initiate safety injection. Only one event, however, had a flow rate that even approximates a full double-ended tube rupture as described in the FSAR; the other four events were much smaller in magnitude.

Q.10 Based on this historical data alone, what would be the predicted failure rate for steam generator tubes in Westinghouse type PWRs?

A.10 With five tube ruptures in an experience base of 3.6×10^6 tube years, the experienced tube rupture failure rate would be $\lambda = 5 \div (3.6 \times 10^6) = 1.4 \times 10^{-6}$/tube-year or, using Chi-square tables, the 50 percent confidence value would be

$$\lambda_{50\ \text{percent}} = \frac{11.34}{2 \times 3.6 \times 10^6} = 1.6 \times 10^{-6}\text{/tube-year}$$

with upper and lower 95 percent confidence limits of

$$\frac{21.03}{2 \times 3.6 \times 10^6} \geq \lambda \geq \frac{5.23}{2 \times 3.6 \times 10^6}$$

$$2.9 \times 10^{-6} \geq \lambda \geq 0.73 \times 10^{-6} \text{ per tube-year}$$

Based on this calculation, the tube failure rate derived from experience is 1.6×10^{-6}/tube-year. This is equivalent to the figure of one failure in 45 years that I mentioned previously. It could be as low as 0.73×10^{-6} or as high as 2.9×10^{-6} per tube-year.

Q.11 Is there any reason to believe that the steam generator tube failure rate for the Harris Plant steam generators is likely to be better than the historical average?

A.11 Yes, because of advances in the state of the art in the design, operation, and inspection of steam generators, it is believed that nuclear plants utilizing Model D steam generators, such as Shearon Harris will be less likely to experience steam generator tube failure. Cogent reasons can be given as to why certain of the five tube ruptures experienced to date should not occur in the Model D steam generators since the operating conditions at certain of the plants which have experienced tube ruptures are not applicable to the Harris Plant. Cogent reasons can also be given as to why the occurrence rate should be substantially less because of design and inspection advancements. These are described below.

Q.12 What were the causes of the five steam generator tube rupture events experiened in Westinghouse-design plants?

A.12 At Plant E[1] in February 1975, phosphate wastage had thinned tubes in a zone just above the tubesheet where sludge had collected. In addition to thinning, some stress corrosion cracking was also present. The events at Plant I in September 1976, and Plant bb in June 1979, show some similarities.

In both cases, the tubes had suffered stress corrosion cracking starting from the primary side. At Plant I, this was due to denting accompanied by "hour glassing" of the flow slots. At Plant bb, the affected tube had excessive ovality which led to high stresses at the U-bend. The two remaining events, at Plant N in October 1979, and Plant C in January 1982, were both due to foreign objects fretting and wearing the tube along one side.

Q.13 Why do you believe that the changes which have been incorporated into the design and operation of Harris Plant steam generators are likely to reduce the steam generator tube failure rate?

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1 Plant designations refer to notation used in Tables 1 through 6.

A.13 Due to advances in the design of Model D steam generators and in operations, maintenance, and inspection procedures at Harris, tube failure resulting from these causes is judged to be reduced in frequency[2]. The phosphate wastage, for example, has been eliminated since phosphates will not be used at Harris, thus the tube rupture frequency attributed to wastage is judged to be lowered by at least a factor of 100. A reduction factor is utilized even though phosphate wastage is impossible at Harris, because other types of chemical wastage (currently unobserved) may still be possible.

Denting of tubes, if it occurs at all, will develop much more slowly and to a more limited extent than in steam generators at other plants because of:

- plant operation with only AVT chemistry control;
- reduction of copper in the secondary side systems as compared to other plants;
- fresh water condenser cooling with resultant decrease in chloride concentrations as compared to plants operating on sea or brackish water.

Stress corrosion cracking (SCC) at Harris is judged very unlikely because of the following:

- limitation of the use of copper which decreases the rate of SCC by reducing the concentration of alkaline salts; and

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2 (Note of Counsel) These design advances and operational commitments were described in detail in the affidavits of Thomas E. Timmons, Glenn E. Lang, and Alan B. Cutter, filed in support of "Applicants' Motion for Partial Summary Disposition of Joint Contention VII (Steam Generators)." The Board granted Applicants' motion and the factual issues addressed therein are not in dispute. See Tr. 2167-68 (Conference Call, July 12, 1984).

- design advances which (a) minimize crevices between the tube and tubesheet through full depth expansion of tubes and (b) provide features to reduce the accumulation of overlying sludge.

In addition, any tube degradation at Harris will most likely be identified before rupture could occur due to extensive In-Service Inspection which includes: full inspection of all tubes before the plant is put into operation, eddy current testing, ultrasonic inspection techniques, profilometry probes, and continuous monitoring of water quality, radioactivity, leakage rates, etc. For these reasons, tube rupture due to denting and SCC is judged to be reduced by a factor of five.

One type of tube leakage event which is not affected by design advances is wear due to foreign objects, which was responsible for the two largest tube rupture events which have occurred. However, due to rigorous quality assurance procedures as well as monitoring for loose parts at Harris, this type of tube leakage event is judged to be much less likely than historical frequency indicates, and a lowering by a factor of two is assumed in this study.

Implementation of the modifications to minimize tube vibration in the Model D-4 steam generators should reduce tube vibration levels such that they will be at or below the levels contained in the experience base used in this analysis.

Q.14 Based on the improvements incorporated into the Harris Plant steam generator design and operation, what steam generator tube failure rate would you predict for the operation of Harris steam generators?

A.14 Given the design, maintenance inspection technique and operating advances described above, the number of historical tube rupture incidents which are applicable to Harris for this analysis can be decreased from five to about 1.5 (virtually none due to phosphate wastage, 0.4 due to denting and SCC, and one due to loose parts).

Table 8 shows how the 50 and 95 percent confidence level failure rate decreases as the number of tube ruptures in the experience base to the present decreases.

On this basis, the median (50 percent confidence level) failure rate would be $\lambda_{50\ percent} = 0.6 \times 10^{-6}$/tube-year. Although the above approach utilizes some engineering judgment in conjunction with the experience base, the data available and identified advances provide reasonable support for this. In fact, engineering judgment would suggest that the advances in the state of the art should yield an even lower failure rate.

This failure rate of 0.6×10^{-6}/tube-year corresponds to an annual frequency of 8.2×10^{-3} per year

$$\left(\frac{0.6 \times 10^{-6}}{\text{tube-year}} \times \frac{\text{4578 tubes}}{\text{SG}} \times 3\ \text{SG} = \frac{8.2 \times 10^{-3}}{\text{year}}\right)$$

at Harris, or one event in approximately 120 years of reactor operation. This predicted value is significantly below the historical base. Thus the operation of Model D-4 steam generators at Harris as compared with previous experience should result in an even higher degree of public safety with respect to these issues.

Q.15 Why shouldn't multiple tube rupture events be considered in analyses of design basis accidents?

A.15 Multiple tube rupture events should not be considered in analyses of design basis accidents due to their low frequency of occurrence and due to their insignificant contribution to risk.

Q.16 Have you determined the frequency of multiple tube ruptures in Westinghouse PWRs?

A.16 Analyses have been performed to assess the frequency of multiple tube ruptures in Westinghouse PWRs. Since a multiple tube rupture has never occurred, a probabilistic model based on pressure differentials across the steam generator tubes was developed to evaluate the frequency of these events.

Q.17 Briefly describe the "pressure pulse" model developed to evaluate the frequency of multiple tube ruptures.

A.17 The "pressure pulse" model relates the pressure differential across steam generator tubes to tube failure probability. Based on laboratory testing, the minimum tube burst capability at the beginning of tube life is assessed at 10,000 psi. The tubes are assumed to degrade linearly from 0 to 40 years of service life.

The model applies a conservative distribution to the individual tube failure probability; the binomial distribution is then used to calculate the probability that one, two, or three tubes fail. The model assumes that during normal reactor operation, transient pressure swings up to about the 2500 psia safety valve set point occur with a frequency of once per year. The "pressure pulse" model is described in detail in Exhibit A.

This model was used to estimate the frequency of single and multiple tube ruptures. The calculated single tube rupture frequency of 7.5×10^{-3} per year is consistent with the value of 8.2×10^{-3} per year calculated from tube experience data.

Q.18 What do you calculate the multiple tube rupture frequency to be for steam generators at the Harris Plant?

A.18 Using the "pressure pulse" model described above, the multiple tube rupture frequency calculated for the Harris Plant is 7×10^{-5} per year. This corresponds to one such event in about 14,000 plant years.

Q.19 Does the risk of multiple tube rupture events contribute significantly to overall risk for the Harris Plant?

A.19 A number of PRA studies have been performed in the United States and Europe which have evaluated the risk to the public from single and multiple steam generator tube rupture initiating events. Results of these PRA studies show that tube ruptures would not contribute significantly to overall risk for a plant such as Shearon Harris.

Based on results of PRA analyses, the Harris core melt frequency due to tube rupture initiating events was estimated to be about 3×10^{-7} per year. Of this frequency, three percent (1×10^{-8} per year) is due to multiple tube rupture events. Applying representative PRA consequence models, the public risk from multiple tube rupture events is judged to be an insignificant contributor to overall plant risk at a plant such as Shearon Harris.

Q.20 Is this assessment of the low risk of tube rupture events consistent with independent evaluations of the NRC?

A.20 This assessment is consistent with the independent NRC evaluation performed in draft NUREG-0844, which concludes that SGTR events beyond the design basis do not contribute a significant fraction of the risks associated with other reactor events at a given site.

Q.21 What are your conclusions regarding the frequency of multiple tube ruptures at the Harris Plant?

A.21 Based on the analysis described above and my experience in other assessments, I am confident that multiple tube rupture events will not contribute significantly to overall public risk at Harris. Due to the relatively insignificant contribution of multiple tube ruptures to public risk, there is little benefit to be gained from performing a vigorous analysis of the consequences of such an event. This assessment reflects the significant design improvements that have been incorporated in Westinghouse Model D-4 steam generator and the improvements in steam generator operations, maintenance and inspections which provide additional assurance of the safe operation of the Harris Plant.

TABLE 1

STEAM GENERATOR TUBE EXPERIENCE TO JULY 1983
U.S. WESTINGHOUSE INCONEL PLANTS

Plant	No. of Tubes	Commercial Operation	Years	Tube-Year
A	11,382	1/68	15.4	$17.5 \times 10^{+4}$
B	15,176	1/68	15.4	$12.4 \times 10^{+4}$
C	6,520	3/70	13.2	$8.6 \times 10^{+4}$
D	9,780	3/71	12.2	$11.9 \times 10^{+4}$
E	6,520	12/70	12.5	$8.2 \times 10^{+4}$
F	6,520	10/72	10.7	$7.0 \times 10^{+4}$
G	10,164	12/72	10.5	$10.7 \times 10^{+4}$
H	9,780	12/73	9.5	$9.3 \times 10^{+4}$
I	10,164	5/73	10.1	$10.3 \times 10^{+4}$
J	13,040	7/74	8.9	$11.6 \times 10^{+4}$
K	13,552	10/73	9.7	$13.1 \times 10^{+4}$
L	9,780	9/73	9.7	$9.5 \times 10^{+4}$
M	13,552	9/74	8.7	$11.8 \times 10^{+4}$
N	6,776	12/73	9.5	$6.4 \times 10^{+4}$
O	6,776	6/74	9.1	$6.2 \times 10^{+4}$
P	6,776	12/74	8.5	$5.8 \times 10^{+4}$
Q	13,552	8/75	7.8	$10.6 \times 10^{+4}$
R	13,552	5/76	7.1	$9.6 \times 10^{+4}$
S	13,040	8/76	6.8	$8.9 \times 10^{+4}$
T	10,164	4/77	6.2	$6.3 \times 10^{+4}$
U	13,552	6/77	6.0	$8.1 \times 10^{+4}$
V	10,164	12/77	5.5	$5.6 \times 10^{+4}$
W	13,552	7/78	4.9	$6.6 \times 10^{+4}$
X	10,164	6/78	5.0	$5.1 \times 10^{+4}$
Y	10,164	12/80	2.5	$2.5 \times 10^{+4}$
Z	13,552	7/81	1.9	$2.6 \times 10^{+4}$
A1	13,552	10/81	1.7	$2.3 \times 10^{+4}$

TABLE 1 (Continued)

STEAM GENERATOR TUBE EXPERIENCE TO JULY 1983

U.S. WESTINGHOUSE INCONEL PLANTS

Plant	No. of Tubes	Commercial Operation	Years	Tube-Year
A2	10,164	7/81	1.9	$1.9 \times 10^{+4}$
A3	18,696	12/81	1.5	$2.8 \times 10^{+4}$
A4	13,552	6/82	1.0	$1.4 \times 10^{+4}$
Total			233.4	245.6×10^{4} Tube Years

TABLE 2

STEAM GENERATOR TUBE EXPERIENCE TO JULY 1983
WESTINGHOUSE FOREIGN PLANTS (INCONEL)

Plant	No. of Tubes	Commercial Operation	Years	Tube-Year
AA	2,604	8/69	13.8	$3.6 \times 10^{+4}$
BB	5,208	12/69	13.5	$7.0 \times 10^{+4}$
CC	5,208	3/72	11.2	$5.8 \times 10^{+4}$
DD	10,164	11/74	8.6	$8.7 \times 10^{+4}$
EE	10,164	5/75	8.1	$8.2 \times 10^{+4}$
FF	6,776	4/78	5.2	$3.5 \times 10^{+4}$
GG	13,552	3/79	4.2	$5.7 \times 10^{+4}$
HH	14,022	4/81	2.2	$3.1 \times 10^{+4}$
II	14,022	12/81	1.5	$2.1 \times 10^{+4}$
JJ	9,156	12/81	1.5	$1.4 \times 10^{+4}$
Total			69.8	49.1×10^{4} Tube Years

TABLE 3

STEAM GENERATOR TUBE EXPERIENCE TO JULY 1983
MHI PLANTS

Plant	No. of Tubes	Commercial Operation	Years	Tube-Year
ZZ	6,520	7/72	10.9	$7.1 \times 10^{+4}$
YY	10,164	11/75	7.6	$7.7 \times 10^{+4}$
XX	6,776	10/75	7.7	$5.2 \times 10^{+4}$
WW	10,164	12/76	6.5	$6.6 \times 10^{+4}$
VV	6,776	9/77	5.7	$3.9 \times 10^{+4}$
UU	6,776	3/81	2.2	$1.5 \times 10^{+4}$
TT	6,776	3/82	1.2	$0.8 \times 10^{+4}$
Total			41.8	32.8×10^{4} Tube Years

TABLE 4

STEAM GENERATOR TUBE EXPERIENCE TO JULY 1983
FRAMATOME PLANTS

Plant	No. of Tubes	Commercial Operation	Years	Tube-Year
a	10,164	12/77	5.5	$5.6 \times 10^{+4}$
b	10,164	3/78	5.2	$5.3 \times 10^{+4}$
c	10,164	2/79	4.3	$4.4 \times 10^{+4}$
d	10,164	2/79	4.3	$4.4 \times 10^{+4}$
e	10,164	7/79	3.9	$4.0 \times 10^{+4}$
f	10,164	12/79	3.5	$3.6 \times 10^{+4}$
g	10,164	11/80	2.6	$2.6 \times 10^{+4}$
h	10,164	12/80	2.5	$2.5 \times 10^{+4}$
i	10,164	9/80	2.7	$2.7 \times 10^{+4}$
j	10,164	12/80	2.5	$2.5 \times 10^{+4}$
k	10,164	12/80	2.5	$2.5 \times 10^{+4}$
l	10,164	6/81	2.0	$2.0 \times 10^{+4}$
m	10,164	5/81	2.1	$2.1 \times 10^{+4}$
n	10,164	2/81	2.3	$2.3 \times 10^{+4}$
o	10,164	5/81	2.1	$2.1 \times 10^{+4}$
p	10,164	12/82	1.5	$1.5 \times 10^{+4}$
q	10,164	10/81	1.7	$1.7 \times 10^{+4}$
r	10,164	11/81	1.6	$1.6 \times 10^{+4}$
s	10,164	12/81	1.5	$1.5 \times 10^{+4}$
t	10,164	11/82	0.6	$0.6 \times 10^{+4}$
	Total		54.9	55.5×10^{4} Tube Years

TABLE 5

STEAM GENERATOR TUBE EXPERIENCE TO JULY 1983

MISCELLANEOUS WESTINGHOUSE LICENSEE PLANTS

ACECOWEN

Plant	No. of Tubes	Commercial Operation	Years	Tube-Year
aa	6,520	2/75	8.2	$5.3 \times 10^{+4}$
bb	6,520	11/75	7.6	$5.0 \times 10^{+4}$

ACLF

Plant	No. of Tubes	Commercial Operation	Years	Tube-Year
cc	10,164	9/75	7.7	$7.8 \times 10^{+4}$
Total			23.5	18.1×10^{4} Tube Years

TABLE 6

SUMMARY OF STEAM GENERATOR TUBE EXPERIENCE TO JULY 1983

	No. of Plants	Plant-Years	Tube-Years
Westinghouse (Inconel Tube)			
US plants	31	233.4	2,456,000
Foreign plants	10	69.8	491,000
Subtotal	41	303.2	2,947,000
Westinghouse Licensee plants			
MHI	7	41.8	328,000
FRA	20	54.9	555,000
Miscellaneous W Licensee Plants	3	23.5	181,000
Subtotal	30	120.2	1,064,000
TOTAL	71	423.4	4,011,000

TABLE 7

TUBE RUPTURE EXPERIENCES SUMMARY

No.	Occurrence Date	Plant	Attributed Cause	Estimated Leak Rate
1	Feb. 26, 1975	E	Phosphate Wastage + SCC	125 gpm (1)
2	Sept. 15, 1976	I	Denting + SCC	80 gpm (1)
3	June 25, 1979	bb	Ovality + SCC	135 gpm (1)
4	Oct. 2, 1979	N	Loose part (spring)	390 gpm (1)
5	Jan. 25, 1982	C	Loose part (plate)	634 gpm (2)

Ref.

1. NUREG-0651, Evaluation of Steam Generator Tube Rupture Events, USNRC, Appendices Card H, March 1980.

2. Response to Long Term Commitments, Ginna Restart SER, Steam Generator Tube Rupture Incident, November 22, 1982, Attachment B, Analysis of Plant Response During January 25, 1982, Steam Generator Tube Failure at the R. E. Ginna Nuclear Power Plant.

TABLE 8

SENSITIVITY OF TUBE FAILURE RATE TO NUMBER OF FAILURES EXPERIENCED

Assumed No. of Failures Experienced in 3.6E+06 Tube Years of Operation	Corresponding Failure Rate at Indicated Confidence Level: 50 percent	Corresponding Failure Rate at Indicated Confidence Level: 95 percent
5	1.6×10^{-6}/Tube Year	2.9×10^{-6}/Tube Year
4	1.2×10^{-6}	2.5×10^{-6}
3	1.0×10^{-6}	2.2×10^{-6}
2	0.74×10^{-6}	1.8×10^{-6}
1.5	0.60×10^{-6}	1.5×10^{-6}
1	0.47×10^{-6}	1.3×10^{-6}
0	0.19×10^{-6}	0.83×10^{-6}

This exhibit describes the pressure pulse model used to quantify the probability of multiple tube rupture events at the Shearon Harris Nuclear Power Plant.

The 6×10^{-7} per tube-year rupture frequency calculated from the modified experience base is the frequency of degradation to the extent of rupture under the normal operation tube differential pressure load in the range of 1250 psi. The frequency of degradation to the extent of rupture under increased pressure loads is assumed to be of this magnitude also. The model assumes that for a tube that does degrade to this extent, it may take anywhere from 0 to 40 years of operation with equal probability.

For this analysis, transient pressure swings up to the 2500 psia safety valve set point (a pressure differential of 1500 psi) are assumed to occur with a frequency of once per year. The time that a degrading tube spends in the 1500 to 1250 psi capability range is thus estimated to be:

$$t^* = t \left[\frac{L_T - L_{NO}}{L_I - L_{NO}}\right]$$

Where:

L_T = the tube capability of a tube failing under a transient load

L_{NO} = the capability of a tube that fails under normal operating loads

L_I = the initial minimum virgin tube burst capability

t = the time for a tube to degrade to 1250 psi capability

This model is shown in Figure A-1.

For the case of a normal transient, L_T is 1500 psi and L_{NO} is 1250 psi (normal operating load). Based upon laboratory testing, the minimum virgin tube burst capability is assessed at 10,000 psi. The time to degrade, t, is assumed to be uniformly distributed from 0 to 40 years of service life. On the average (i.e., the mean time to failure), the time for a tube to degrade would be T/2, or 20 years.

Thus, for this case

$$t^* = [\frac{1500 - 1250}{10,000 - 1250}] t = .029t$$

This model does not presume a great level of detail regarding the shape of the tube degradation curve. Although a variety of convex or concave degradation curve shapes are theoretically possible (provided that the tube capability monotonically decreases), a uniform linear rate was used in this model to provide some average sense that the time a failing tube spent in any given strength band is proportional to the width of the band.

Given a transient event, the probability that a tube exposed to a 1500 psi differential pressure would rupture is

1. $p = \lambda t^* = .029\ \lambda t$ per tube

A weighted average of t* is calculated, yielding a value of 0.59. Thus,

$$p = \lambda t^* = 0.59\lambda$$

The transient pressure differential is applied to all three steam generators. Based on this and the assumption that each tube's failure probability is random and independent, the probability of various numbers of tubes rupturing can be evaluated from the binomial distribution.

$$2.\quad \underline{P}(r) = \frac{n!}{r!(n-r)!} p^r \times (1-p)^{n-r}$$

Where: n = number of steam generator tubes = 4578 x 3 = 13,734

r = number of tubes rupturing, i.e., 1 or 2 or 3

p = probability of individual tube failure from Eq. 1

$\underline{P}(r)$ = probability of r tubes failing.

To account for the dependence between steam generator tubes, the method of discrete probability distributions (DPDs) was used to quantify P^r in the above expression. The DPD method is useful when analyzing components of the same type (e.g., steam generator tubes) which have identical probability distributions (or pdfs). These pdfs are not only identical, they are dependent in the sense that, if one were somehow to learn the true failure rate of component 1, this would certainly affect the state of knowledge about the failure rate of component 2. Note, however, that this does not mean that one would know the failure rate of component 2 exactly because, although it is the same type of component, it is physically distinct. The DPD for the second component, however, would be narrower.

A probability distribution for λ was assigned as follows. The five plants which have had tube rupture events make up about 10 percent of the tube experience base. The experienced tube rupture frequency for these "worst" plants (1.5 events/3.6 x 10^5 tube-years = 4.2 x 10^{-6} events/tube-year) is assigned a probability of 10 percent. The median value calculated above was assigned a probability of 80 percent; the lower tail, from the Chi-square tables, was assigned a 10 percent probability. The following distribution is thus assigned for λ:

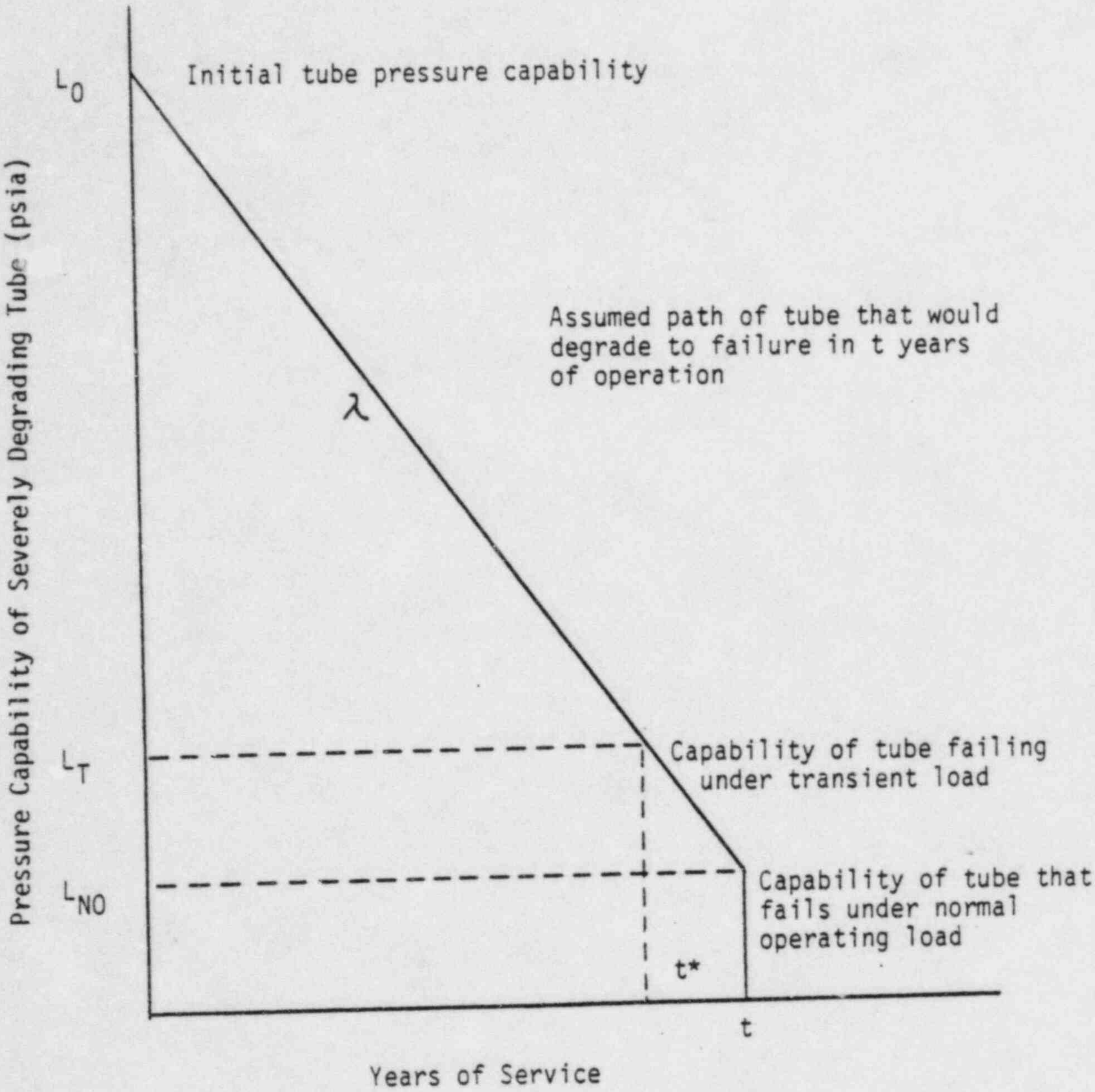
Probability	λ
.1	4.2 x 10^{-6}
.8	6.0 x 10^{-7}
.1	1.6 x 10^{-7}

This model gives the results listed below for rupture of one, two, or three tubes. Since the frequency of these transients has been presumed to be once per year, these probabilities also constitute annual frequencies. These results show a multiple tube rupture frequency of 7 x 10^{-5} per year.

Number of Tubes Rupturing	Probability
1	7.5 x 10^{-3}
2	6.7 x 10^{-5}
3	6.7 x 10^{-7}

FIGURE A-1

MODEL FOR PROBABILITY OF TUBE RUPTURE ON LOAD INCREASE



λ = Frequency of severe degradation or rupture (per tube year)

t = Time to fail under normal load (assumed random over period 0 to 40 years

t*= Time vulnerable to credible steam break load (years)

$$t^* = t \left[\frac{L_T - L_{NO}}{L_0 - L_{NO}}\right]$$

P = Probability of failure given steam break loads = λt^*

$$= \lambda t \left[\frac{L_T - L_{NO}}{L_0 - L_{NO}}\right]$$

MR. EDELMAN: May I inquire as to which numbers were transposed, did you ever put out a correction to the affidavit?

BY MR. O'NEILL: Mr. Hitchler, would you please refer to your prepared statement and, for the record, indicate which numbers were transposed so that the point will be clear?

A If you turn to page 9 of my testimony --

MR. EDELMAN: The August 9 testimony?

A That's correct.

As I stated, two numbers were juxtaposed, and what they were were were, I talk about reduction factors that I expect to see the experience demonstrate based on improvements in design and operation. And what the numbers are is that if you take the first paragraph that begins with "In addition" and you go to the last line in that paragraph, in the affidavit that 5 was a 2.

In the next paragraph that follows, in the last sentence, the last phrase is "and the lowering by a factor of 2 is assumed" In the affidavit, that number was a 5. As I said, the two numbers were just reversed in the base analyses.

MR. O'NEILL: Thank you, Mr. Hitchler.

Before offering our witness for cross-examination, I'd ask Mr. Hitchler, for the benefit of anyone here in the room who has not had an opportunity to read his statement, if he would briefly summarize his testimony.

JUDGE KELLEY: Yes, please do.

THE WITNESS: My testimony is in direct response to Joint Intervenor's Contention 7, part four, which states:

"Steam generator tube rupture analysis found in FSAR is inadequate because it fails to consider multiple tube rupture events."

My conclusion is that I strongly disagree with that statement. My testimony discussed the analysis in which I came to that conclusion. But the two basic reasons why I come to that conclusion is, number one, that the frequency of multiple tube ruptures is exceedingly small compared to events we normally consider in the FSAR analyses. Also, that in terms of the risk contribution from these types of events, in other words, the approaches to safety goals or safety margins that in terms of that context, multiple tube ruptures do not represent an unusual risk. They are not risk contributors.

To further elaborate on that statement in both areas, you're saying right now that single tube rupture events have a historical recurrent interval of approximately once every 40 years. They are still rare events not expected to happen during the lifetime of the plant, but they are rare events. We feel that the improvements in the design and in operation would justify a number much lower than this. In other words, the number we show is approximately once in every 120 years. But the trends are clearly in the less frequent range.

From the standpoint of multiple tube rupture events, an historical record shows that there have been zero events to date.

My testimony discusses models that can be used for predicting what may be the actual reccurence intervals. The numbers are are talking about here are more in the range of 1 in 10,000 to 14,000 years of operation. So they are trivially small compared to the events that are analyzed in the FSAR currently.

Also, from the standpoint of risk perception that the multiple tube rupture events in terms of core degredation or other types of events like this, these events do not represent a significant portion of events that are normally classified into these severe accidents. So therefore, we meet a very low frequency for the initiator and we also meet a very low risk contribution in terms of other events.

So therefore, I see no real basis or benefit to be achieved by going through a very rigorous analysis in an FSAR type method.

MR. O'NEILL: Mr. Chairman, Mr. Hitchler is available for cross examination.

JUDGE KELLEY: Thank you.

Mr. Runkle or Mr. Edelman, who is doing the cross examination of this witness?

MR. EDELMAN: I am.

JUDGE KELLEY: All right.

CROSS EXAMINATION

BY MR. EDELMAN:

Q Mr. Hitchler, let's start at the end of your summary. I believe you said that there was no benefit to going through a very rigorous analysis in an FSAR of multiple tube rupture events. Do you maintain that what you've done here in your testimony is that sort of very rigorous analysis?

A No, I am not saying that my analyses is in an FSAR context.

Q Well, let's see if we can explore that a little bit.

Have you ever prepared analyses of the steam generator tube rupture events for an FSAR?

A I have not.

Q Are you familiar would you say with the methodology and the requirements for such an analysis?

A I'm familiar with the methodologies and I have supervised individuals doing this type of analysis.

Q And so you know what is required to be done in such an analysis, is that right?

A In general, yes.

Q In general.

Let me see if you can give me some specifics?

What is required for an FSAR analysis of steam generator tube rupture?

A Well, could you clarify that question in terms of -- it's a very broad field.

Q Well, you said that you supervised people doing it. Therefore, I presume that you know what they have to do. Because otherwise you could not supervise that. Wouldn't that be correct?

A Yes.

Q Okay.

Now, in preparing an analysis for FSAR -- maybe we can clarify this a little by backing up. I want to come back to where we were before. The safety analysis in an FSAR -- you have described some term s in your summary here that have to do with that. There's an initiator of an event, there is a consequence, and so forth, correct?

A Yes.

Q Okay. Now -- let me ask you this. Are there formal NRC guidelines which specify the sort of analysis, the rigor of the analysis that's required for this risk estimation in an FSAR, are there formal guidelines on that?

A Yes, there are.

Q Are you familiar with those guidelines?

A I'm familiar with what they are.

Q You know what they are?

A Where they are located, yes.

Q Okay. So, if you needed to find out what the requirements were for some type of analysis in an FSAR, you could go look it up?

A Yes.

Q But you might not know off the top of your head what those requirements are?

A Not every detail.

Q Are there any specifics to tube rupture in those requirements or are they more general than that?

A There are specific requirements. Again, we're talking about a very broad set of conditions that must be met.

Q Okay. Did the specifics talk about tube rupture explicitly?

A Yes. The specifics talk about a tube rupture accident and a number of assumptions or conservatisms that should be applied to the analysis.

Q What are those conservatisms?

A Well, just to -- I'll give you several examples that I can get off the top of my head.

You must assume that you have a full double-ended rupture single tube at the worst location. You must assume that the core physics and heat transfer of the core conditions are at their peak maximized potential for DNB. You must assume single failures, you must eliminate single failures, as we do in all analyses.

Q Okay. Let me go back through that and just check a couple points.

Full double-ended tube rupture is the same thing you refer to in your testimony here, is it not?

A The word that I would use in doing the analysis is that there is a double-ended tube rupture. In terms of what we've experienced in the data base, there's quite a difference.

Q Well, when you speak of the requirement for analysis for a full double-ended tube rupture in your testimony, you're talking about the same thing that's in the requirements, is that correct?

A Yes.

Q You say " at the worst location". Do you analyze what that worst location is or is that specified in the requirements?

A You must demonstrate that it's the worst conditions.

Q So what you have to demonstrate is that there is no place that would be worse to have the double-ended tube rupture than the place where you assume it happens in your analysis of the FSAR?

A That's correct.

Q Okay. And the Staff looks at that and approves it; is that the way it works?

A Yes.

Q Okay. Now, you refer to core heat and heat transfer being at peak. That means, in essence, that's as much heat as the thing is allowed to put out; is that correct?

A Yes.

Q And DNB, that's departure from nucleate boiling?

A That's correct.

Q Okay. Could you just explain that for a moment, what DNB is -- what the phenomenon is, I mean?

A The basic phenomena is just that your heat transfer rate -- meaning from the fuel pallets through the clad and into the coolant, essentially -- changes drastically at a certain point. That's when you depart from nucleate boiling. What happens is that the fuel cannot heat up much faster at that point. There is a higher potential for fuel damage under those conditions.

Q Okay.

And the event that makes that additional heat up possible is this departure from nucleate boiling?

A Yes.

Q And that is a change in the condition of the coolant; is it not?

A It could be.

Q Okay.

Does the pressure of the coolant have anything to do with how close you come to this departure from nucleate boiling?

WRB/pp 13

A Yes.

Q And isn't it true that if the pressure drops that you, in general, would come closer to departure from nucleate boiling?

A Yes.

Q Okay.

And the pressure differential across these tubes, when you are operating the plant, is about 1,000 pounds per square inch, is it not?

A Yes.

3 fls.

WRB/agbl

Q Now let's see, we have gone through two of the requirements. I cannot recall off the top of my head, is there another requirement for that analysis that you mentioned before?

A. There are several requirements. The one I mentioned was single failure.

Q Okay.

And that assumes -- Is the tube rupture the single failure or is it one other single failure?

A. It is one other single failure.

Q Okay.

One other single failure of any component or system?

A. Yes.

Q Okay.

Now those are the sorts of requirements for analysis for a single tube rupture, correct?

A. Yes, it is.

Q Now what I was asking you about at the beginning was what the analysis would be for an FSAR if you had actually considered multiple tube ruptures.

Now would the analysis for multiple tube ruptures fall under the same requirements or would the requirements be different if you had to do that for an FSAR?

A. Well the requirements are a condition of what the frequency of the accidents are; in other words, the limits that we are applying to the accidents.

Q Okay.

A So therefore that is difficult to answer because the two are intertwined as to what our analysis criteria is and also what analysis assumptions must be demonstrated to meet acceptance..

Q So what you are saying is that what the FSAR would require in the analysis of an event depends on the probability of that event, among other things?

A Yes.

Q That is part of what you are saying?

A It is part of it.

Q Okay.

Now let me ask you about the probability part of this.

You refer in your testimony on page two -- I gather there is not a page one, is that right? The cover sheet is page one?

A The cover sheet is page one.

Q Okay.

And on pages two and three you talk about what we might term your general experience, do you not?

A Yes.

Q Now what training do you have in probability and statistics?

A. I have several courses that I received in school. Most engineers receive those.

I have also attended several courses in this specific technology, the use of different statistical distributions inside and outside of Westinghouse. Also I have had numerous applications of this technology in the studies that have been mentioned and have been through peer review on those analyses.

MR. O'NEILL: If you could get closer to your microphone. It is a little difficult to hear you.

BY MR. EDDLEMAN:

Q. So these courses you have taken inside and out of Westinghouse, are they formal classes with exams or are they seminars or what were they?

A. It was a mixture. Some of them were very formalized courses; one in particular at Carnegie-Mellon University was a four and a half month course in strictly engineering-applied statistics at the graduate level.

Q. And you completed that course?

A. Yes, I did.

Q. Okay.

The assessment of probability involves statistical methodology and also some judgment as to what data to use, does it not?

A. That's correct.

Q. And in fact in your testimony you make a number of judgments about what data is appropriate to use for probability of a single steam generator tube rupture, do you not?

A. That's correct.

Q. Now the base data, to the extent that you presented it, is contained in these tables that are appended to your testimony, is that not correct?

A. That's correct.

Q. Okay.

If we just look through here, Table One, Steam Generator Tube Experience to July 1983, U.S. Westinghouse Inconel Plants;" now I take it from that that these are plants with a nuclear steam supply system made by Westinghouse located in the United States which have Inconel alloys as the steam tubes in the steam generators, is that correct?

A. That's correct.

Q. Okay.

Are there different Inconel alloys that are used in these plants?

A. There are several variations.

Q. Are these plants arranged in such a way that you can pick out the ones that, say, were Inconel 600 and others that were other Inconel alloys?

A. No, they are not.

Q. Do you know which alloys go with which plants?

A. I could pick those out. That is in an even more plant-specific data base.

Q. And you have that data base?

A. Yes, we do.

Q. Do you have it with you?

A. No, I do not.

Q. Okay.

In fact these plants are identified solely by letters and numbers and not by their actual names in this table, is that correct?

A. That's right.

Q. Okay.

Now at the end of that table, page 15, we have a total number of tube-years of 245.6 times 10 to the 4, which is about 2.5 million tube-years, is that correct?

A. That's correct.

Q. Okay.

Now then in Table Two, "Steam Generator Tube Experience to July 1983, Westinghouse Foreign Plants Inconel," now these are also Westinghouse nuclear steam supply system plants located outside the United States with Inconel steam generator tubes, I take it, is that correct?

A. That's correct.

Q. And the total number of tube-years there is 49.1 times 10 to the four, or about half a million tube-years?

A. That's correct.

Q. Okay.

Now then you have "Steam Generator Tube Experience to July 1983...," for "MHI Plants."

What is an MHI plant?

A. MHI stands for Mitsubishi Heavy Industries, they are our licensee in Japan..

Q. Do these plants all have Inconel steam tubes?

A. Yes, they do.

Q. Do you know which Inconel alloys are used in them?

A. We have that data. I don't have it with me.

Q. Do you know if they are the same alloys that are used in the plants in the United States?

A. Yes. We set the specifications as to what materials should be used and our functional requirements.

Q. When you say -- You say you set specifications.

Do those specifications have to do with the composition of the alloy specifically?

A. Yes.

Q. Okay.

A. That is part of our inherent design that the licensee pays for, those specifications.

Q There are different Inconels, though, that meet those specifications, are there not?

A Yes, there are.

Q Okay.

And do you know whether, in fact, any substitutions were made for those alloys in these plants?

A I know of no exceptions to our requirements in strength and other materials or specifications in the materials to be used in these tubes.

Q Okay.

But would the information get back to you if one of them made a change or if one of them had made a change in one of the older plants, would you know that?

A I'm not certain what you mean by "a change in one of the older plants."

Q Well what I mean is if they varied from the type of Inconel that was specified to some other type or even to some other alloy.

A In my judgment I cannot say specifically we would have noticed that kind of a difference in terms of specifications that were set for either monitoring the tubes or in terms of accident analyses that were being done as part of the licensing process.

Q Are the accident analyses that are required in

Japan the same as are required in the United States?

A. They are at least to the level of what we have.

Q. "At least," you say?

A. Yes.

Q. May they be, in some cases, more rigorous?

A. They may.

Q. Do you know if the steam generator tube rupture analysis requirements in Japan are more rigorous than those in the United States?

A. I cannot answer that. I know the analysis is done to the level that we do it, the tube rupture analysis, at a minimum. In other words, the plant must be licensable in the country of origin.

Q. Right.

And you do not know specifically beyond that what requirements there may be in Japan?

A. No, I do not.

Q. Okay.

Now in your table four, these are "Framatome Plants," now that is the French reactor manufacturer that also is a licensee of Westinghouse, is that correct?

A. That's right.

Q. Do these plants all use Inconel tubes?

A. Yes, they do.

Q. Are they the same alloys that are used in the

United States plants?

A. Yes, they are.

Q. They are the same.

How do you know that?

A. For the same reason that I gave on the Mitsubishi plants.

Q. So the reasons and the extent of your knowledge of it are the same as for Mitsubishi?

A. Yes.

Q. Now in all these tables, including Table Five, the plants are identified by letters or numbers and not by their actual names, correct?

A. That's right.

Q. And Table Five is "Miscellaneous Westinghouse Licensees."

Could you tell us what those licensees are?

A. We have various contractual sub-agreements with other individuals other than Mistubishi or Framatome. I don't recall the exact country of origin where this license was granted. I think they are the Spanish but I am not certain.

Q. All right.

A. Which is essentially a subset of the Framatome.

Q. You do not know if the Alvarez plant in Spain is included in here?

A. The Alvarez plant is included in the data base.

Q. Is it in one of these tables, to your knowledge?

A. Yes.

Q. Okay.

The Ringos plant in Sweden, is that included in your data base?

A. I believe so. Again I would have to go back and verify exactly what dates and criticality. As I said, we accumulated data through the middle of '83.

Q. Yes, I see that.

Now you mentioned criticality just now and I believe it says commercial operation in the tables.

Are these number of years from initial criticality or from commercial operation as declared by the utility operating the plant?

A. As declared by the utility operating the plant.

Q. Okay.

Is the Kirsto plant in Yugoslavia included in your data base?

A. I believe there is a small part. I would have to verify that exactly.

Q. Was it declared to be in commercial operation before July 1983 to your knowledge?

A. It was pretty close. I would have to go back and verify it.

Q Okay.

In deciding which plants to include in this study, are there any plants that are left out of these tables that are Westinghouse nuclear steam supply stations -- systems, pardon me, with Inconel steam generator tubes?

A None to my knowledge.

Q So these tables would include every -- or essentially every -- Well let me ask it this way:

Is every Westinghouse nuclear steam supply system plant in the world with Inconel steam generator tubes in your tables which were declared commercial before July of 1983?

A It would that we have direct access to. I am not aware of any exceptions to our access.

Q Okay.

Now is it true that all of these that are located in foreign countries would have the same requirement on them that you mentioned for the Japanese plants; namely that they would have to have been licensable in their country of origin, the United States?

A Yes.

Q So they would have had to meet, at minimum, the same steam generator tube rupture analysis of an FSAR for a plant in the United States?

A That's correct.

Q Okay.

I would like to go back with you to Table One. Now these plants are listed roughly in order of commercial operation date in this table, are they not?

A Yes, they are.

Q Okay.

I mean there are some minor exceptions to that, but in general the dates go from earlier to later and in general the number of years of operation are less as we go down the table?

A Yes, they are.

Q Okay.

A steam generator tube, to retain its integrity, depends basically on the metal in the tube, does it not?

A Yes, that is one consideration.

Q Well here's what I mean:

These tubes themselves, the tube walls, are what resists rupture or leakage rather than the tube plus something bound around it, through its length, isn't that correct?

A I think that is too general of a statement.

Q All right. Let me see if I can specify it so that we can get to something on this.

The tubes in the steam generator, they go through a tube sheet and various support plates, do they not?

A. Yes, they do.

Q. And between those points which may be supporting -- well let me ask you:

May those points be points of support for those tubes?

A. To some extent, yes.

Q. And they may also be points, may they not, where the tube may be squeezed by corrosion or subject to some other effects?

A. On some plants that has been seen.

Q. Yes.

And some of those plants are Westinghouse plants with Inconel tubes, are they not?

A. Yes.

Q. The tubes between those plates or tube sheets are free-standing, as it were; that is, they are just there standing among the feedwater or steam on that side, I mean on the secondary side, is that right?

A. Yes.

Q. Now that is what I was trying to get at before about the tubes not being supported by anything else.

So in those free-standing areas the protection against rupture is the strength of the tube wall itself?

A. Yes.

Q. Okay.

Now over the lifetime of a tube like this -- well let me back up a second.

What sort of background do you have in metal corrosion or mechanisms of corrosion?

A. My background is basically my academic background in that area.

Q. Which is?

A. Courses in metallurgy. I have no background from the standpoint of my application of that knowledge in Westinghouse at this point.

Q. Okay.

So is it correct to say that you didn't explicitly take account of corrosion mechanisms or processes in your analysis here?

A. No, that is not what my analysis states, which -- I am not physically modeling changes in phase metals and that type of metallurgical issue.

I am analyzing the failures of tubes with respect to different failure mechanisms and looking at the statistics in that fashion.

Q. Okay.

Now in looking at those statistics, you didn't take into account in any explict way, did you, the mechanisms of the corrosion?

A. How do you mean "mechanisms?"

Q Let me try to explore this with you a little bit. I want to come back to that question but let me follow through here.

When a tube is new, a freshly-made Inconel tube put into a Westinghouse steam generator, it should be essentially uncorroded, isn't that correct?

A That's right.

Q Now through its operating life it may well be subject to various forms of corrosion, correct?

A It may, yes.

Q Do you know of any tubes which would not be subject to corrosion in a Westinghouse steam generator with Inconel tubes?

A Given the environment or phenomena that may exist--you have to conditionalize your statement on that, that it is not just a simple process that all tubes will corrode because the data base says that, that there's varying phenomena that can exist and it depends on the way you are planning on operating the plant and various other issues as to whether the tubes will be put into an environment that may lead to corrosion.

Q Okay. Perhaps I didn't phrase that earlier question the way I wanted to.

It is possible for any given tube to be corroded in one of these steam generators, is it not?

A. Given the conditions it is possible.

Q. Okay. And those conditions -- I think we may be getting a little circular here, but those conditions are ones which cause or make more likely corrosion?

A. Yes.

Q. You said that those conditions depend in some part on the way you plan on operating the plant.

Do you know whether the principal -- Let me ask you this:

Do you know what the principal mechanisms of corrosion for steam generator tubes in Westinghouse steam generators which tubes are made from Inconel alloys, what the principal mechanisms for corrosion of those have been historically?

A. Yes.

Q. And what are those?

A. There are a number of these. Just off the top of my head at this point: over the phosphate wastage, denting and stress corrosion cracking, loose parts monitoring. And in fact these are mentioned in my testimony as to what has been the experience base in terms of corrosion and what has been the failure mechanism that has existed at plants that have experienced tube ruptures.

Q. Okay.

Are there other mechanisms of corrosion besides those three you mentioned that these tubes may be subject to?

A. There are. Those are probably found in most of the cases.

Q. The phenomenon of denting, if I may just follow along on this since you have mentioned it, is that, in sort of common-sense terms, the tube having been squeezed by some corrosion around it where it passes through some kind of a supporting member or part?

A. That could be a characterization of the change of phase that occurs in the support plates, yes.

Q. Are these support plates made out of Inconel on these steam generators?

A. No, they are not.

Q. What are they made out of?

A. It is usually carbon steel.

Q. Carbon steel is subject to corrosion under these conditions that prevail outside of the steam generators, isn't it?

A. Given the initial conditions if you don't watch your chemistry, yes.

Q. Now what initial conditions are you referring to?

A. In other words, we are talking about oxide and other materials that could result in a change in the phase of the carbon steel which causes the carbon steel to grow and causes the squeezing phenomenon.

Q "To grow," you mean to expand physically?

A Well in the change of phase the specific volume does change in the material --

Q And that change in specific volume is to increase the volume, correct?

A Yes.

Q And that is what squeezes the tube?

A Yes, if the chemistry isn't maintained correctly.

Q Okay.

Can the chemistry be always maintained correctly, is that something that happens in practice?

A I think it is occuring now. The operating history is showing that we are not experiencing these kinds of failures at this point.

Q You say "failures." Is that sort of corrosion occuring?

A Well the level of corrosion is occurring at very minute levels or very controlled levels which should not cause this kind of denting phenomena in a plant that is maintaining the chemistry.

Q Okay.

So you are saying that the rate of this type of corrosion is less now, is that what you are saying?

A Yes, significantly less.

Q Did you have access to any measurements of it when you reviewed material for preparing your testimony?

A. I didn't have access to exact growth rates. What I had access to was the amount of tubes being plugged due to denting phenomena, these types of issues.

Q. Okay.

Now when you plug a tube, that is due to some weakness or failure in the tubes?

A. Yes. It could be a weakness or just preventive plugging.

Q. Okay.

And "preventive plugging" is when you think it is likely the tube may fail based on some monitoring or study that has been done?

A. No, we have specified very precise safety margins we want to maintain in the tubes, therefore any time the tube wall thickness degrades below a certain points or we think that there is a potential for that happening before the next tube inspection, we will plug it.

In other words, we plug before we expect to ever approach one of our -- what I will call safety thresholds on these tubes.

JUDGE KELLEY: We are going to want to take a break at some near point. Is this as good a place as any or do you want to get a few more questions?

MR. EDDLEMAN: I am trying to think if I can neatly wrap up a little of this or not....

I think we had better just go ahead and take a break.

JUDGE KELLEY: Okay. 10 minutes.

(Recess.)

JUDGE KELLEY: Back on the record.

Mr. Eddleman, will you resume?

THE WITNESS: May I make a correction of something we discussed earlier?

JUDGE KELLEY: Surely.

THE WITNESS: We were talking about Table Number Five on page 19 of my testimony and the question was what plants do these physically represent. And I was mistaken when I thought the plants were of a Spanish design. The plants belong to a generation of units when Westinghouse -- in an agreement with the countries of Belgium and France a number of years ago so they were excluded from the basic data sets. But they all were Inconel of a fairly standard design.

JUDGE KELLEY: Thank you.

BY MR. EDDLEMAN:

Q Before the break we were talking about plugging tubes in the steam generators and I believe you said that there was a criterion for wall thickness that was used to decide when you plug a tube.

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Can you tell me what that criterion is, or does it vary from plant to plant?

A. There is a very precise criterion that is adhered to and in fact required by public law, and that is that if the wall thickness degrades to more than 40 percent the tubes must be plugged. Or if you anticipate degrading more than 40 percent before the next inspection you must do this plugging.

Now plants implement a number of different types of criteria. In other words, that is the maximum allowance. Most plants use a much less -- a much more restrictive requirement if they are plugging criteria.

Q. Okay.

When you say 40 percent is a matter of law, do you mean a Federal statute or do you mean an NRC regulation or a regulatory guide; what is that requirement?

A. There is a reg guide -- excuse me, not a reg guide a NUREG. There is also a steam generator owners' group that has dome up with a series of practices that they feel are prudent operating practices as well as -- call them recommendations by the NRC as to what limits should be allowed.

Q. Well now are those things actual requirements? Would the NRC cite a licensee for violation if they went beyond that?

A. You would have to ask the NRC what the exact compliance with would be on this. I know that it is implemented in that fashion, that they must be met.

Q. Okay.

By "implemented," you mean it is in the technical specifications of these plants?

A. I am not aware that it is in the tech specs, you would have to ask the plant if that is physically in the tech specs or it may be in several other documents.

Q. Okay.

Did you undertake any review of the tube plugging practices of these plants that are in your Tables One through Five or any of those tables in connection with preparing your testimony here?

A. Tube plugging practices with respect to what?

Q. Well let's just say tube plugging practices, period. Did you look at any aspect of it?

A. In other words, I know the years in which plants had major upgrades in their procedures for tube plugging or tube inspection.

As far as my -- I have not been involved in the writing of those kinds of procedures.

Q. All right.

You say you know the years when they had major upgrades. Now what do you define as "upgrade" in tube plugging procedures as being, sir?

A. Upgrade from the standpoint of improved eddy current inspection techniques when the state of the art improved and materials -- or testing became available. Upgrades from the standpoint of when industry groups came up with new criteria for the industry to implement.

Also upgrades from the standpoint of loose parts monitoring devices to detect these things before they degrade the tubes significantly.

Q. Okay.

Would it be fair to say that these upgrades that you are talking about, that you know of, are basically upgrades in the detection of degradation in the thickness of the tube walls or loose parts being on the loose to impact on the tubes rather than upgrades which make more restrictive the requirements for when the tube has to be removed from service in terms of the actual wall thickness of the tube itself?

A. No, it is a mixture of both. There have been a number of tests made on tube strength. We have accumulated data on this type of material as to what thicknesses would the tubes potentially fail at with different types of degradation.

We have an on-going process to evaluate materials and phenomena.

Q What changes then have there been in the wall thickness requirements for tube plugging in these plants using Westinghouse steam generators with Inconel tubes?

A There have not been changes in terms of specific thickness guidelines from what we had before.

Q Have the thickness guidelines always been that 40 percent that you were referring to?

A It was more or less -- again we are getting into an area that we are dealing with licensing issues more, but to my knowledge the 40 percent degradation thickness is something that would have been plugged in the past as well.

Q And to your knowledge that has not changed?

A No.

Q Now you said that some plants implemented on their own more stringent requirements.

Do I take that correctly to mean that the plant might plug a tube even though it was less than 40 percent degraded or might not pass 40 percent loss of tube wall thickness by the next inspection; in other words, it might set a percentage below 40 percent as its criterion, is that correct?

A Yes.

Q Do you know how many of these plants set such criteria?

A. I don't have an itemized list. It is usually tied in with what phenomenon may be occurring at the plant.

For example,if phosphate wastage is possible at a plant, they might want to have a more stringent requirement. It is a plant-specific criterion.

Q. Okay.

Do you know even what percentages of these plants have more stringent criteria than the 40 percent guideline?

A. No, I do not.

Q. Okay.

The plugging of tubes happens in response to a loss of wall thickness, correct?

A. That is one reason, yes.

Q. What are some other reasons?

A. There mav be just preventive plugging that may be prudent in some designs.

Q. If a tube in fact is leaking is it required to be plugged if it is found to be leading during an inspection?

A. Above a certain level, yes.

Q. What is that level?

A. There is a tech spec limit on in-leakage.

Q. That is for the whole primary system or the whole secondary system, right?

A. Yes.

Q. Okay. So it depends on the total amount that is leaked through all tube leaks whether plugging would explicitly be requi.ed in that case, correct?

A. That is the general criteria, yes.

Q. Okay.

Are there more specific criteria which you are aware of that apply to say the plants in Table 1, the American Westinghouse plants?

A. No.

Q. All right.

Now corrosion processes can have the effect of reducing the thickness of the walls of these Inconel tubes in the steam generators, can they not?

A. Yes, they may.

Q. Okay.

And what percentage or proportion, if you know, of the degradations of wall thickness that lead to tube plugging in the plants with these Inconel tubes are due to corrosion and what proportion are due to some of the cause?

A. I don't have the exact numbers. The vast majority is corrosion type.

Q. The vast majority.

Would you say it is like 75 percent or more?

A. Probably more.

Q. Probably more.

Could it be as much as 90 percent?

A. It could be. As I said, I don't have the exact number.

Q. Okay.

The corrosion processes -- well let me ask you this:

Once corrosion has begun in a metal tube like these Inconel tubes in the steam generators, is it more or less likely that corrosion will continue or that further corrosion will take place as opposed to an uncorroded part being corroded from the start under the same conditions?

A. I would say with our current knowledge that that is not correct.

Q. What is correct?

A. That once a corrosion mechanism has been identified with the plant that we have done the analysis, done the research to find -- to identify what caused these mechanisms and we can interdict it. So therefore you should see in general a reduction in the corrosion rates once these corrective measures have been taken.

Q. Okay.

So what you are saying is that once you establish what kind of corrosion is going on you can take corrective measures which slow the rate of that kind of corrosion?

A. That's correct.

Q. Okay.

But.... Well let me ask you this --

A. One thing I want to make certain of is that the corrosion rates I am talking about are severe degradation, not just something that is a standard fouling factor that we use on tubes or other things.

Q. Okay.

A. That would not impact continued operation.

Q. Well now by "severe degradation," do you mean up toward the 40 percent limit?

A. That's correct.

Q. Okay.

The tubes that have been somewhat corroded have some degradation but less than the severe degradation you are talking about are still present in the steam generators once you have taken some measures to reduce the rate of a specific type of corrosion that is causing severe degradation?

A. That's right.

Q. So these tubes may still be corroding either from the same mechanism at a reduced rate or from some other mechanism, may they not?

A. It's possible.

Q. Do you know whether measures to control one type of corrosion may actually potentiate or increase other mechanisms of corrosion?

A. That is part of our evaluation process in making recommendations to reduce corrosion rates is recognizing that there is a balancing process in maintaining chemistry and other factors at certain limits. So we are aware of these numbers of failure mechanisms that may be possible and we recommend the optimal strategy for eliminating this problem or significantly reducing it.

Q. Now by "optimal strategy," do you mean optimal in light of your current knowledge?

A. Yes.

Q. There was a time, was there not, when Westinghouse thought the optimal strategy for eliminating corrosion of these tubes was a phosphate water chemistry, isn't that true?

A. Yes.

Q. That turned out to be incorrect, didn't it?

A. That's right.

Q. Okay.

A. For certain plants. Some plants have not seen this kind of wastage. So it is a balanced approach here. In other words, if we see this kind of corrosion mechanism and we recommend an optimal strategy for recovering from it or reducing it, coupled with this is also a requirement for testing of the tubes and inspection to monitor these things to make sure we have the right strategy.

So it is a two-phase program, not just make a change and then do nothing after that point.

Q Okay.

So you measure the effectiveness of the changes you make in your water chemistry or other operating methods by the degradation which you find in tests of the tubes after you make these changes, is that right?

A. That's right, and factoring in our experience from other plants.

Q Okay.

Do you know why the -- or what the explanation is for the difference between the plants that show phosphate wastage with phosphate water chemistry and those which have phosphate water chemistry but do not show this wastage to that degree?

A. I don't have the answer to that.

Q Let me turn to a slightly different area here.

There are requirements, are there not, for how many tubes in a steam generator have to be usable, that is not plugged, for a plant to be able to continue operation, are there not?

A. Yes, there is -- well there is a requirement for minimum flow capability for the steam generator transfer rates. It isn't always necessarily just the number of tubes.

Q All right.

But knowing the capacities of the tubes for water flow through them and the heat transfer rates from the tubes, you could then translate that into the number of tubes for a given reactor and steam generator, could you not?

A Yes, you could.

Q Okay.

Have there been plants where there have been so many tubes having to be plugged that steam generators had to be replaced?

A Yes, there are.

Q And were any of these plants Westinghouse nuclear steam supply systems with Inconel steam generator tubes?

A Yes, they were.

Q What plants were those?

A There was the Surry 1 and 2 units and the Turkey Point 3 and 4 units.

Q Any others?

A No.

Q Okay.

The number of years of commercial operation that you give in the various Tables One through Five, are those years adjusted in any way for the capacity factor of the plant during its time of commercial operation?

A. They are not.

Q. You have said, have you not, that the way you operate the plant can make a difference in the corrosion rates that you experience.

Do you know whether corrosion tends to proceed faster or slower when the plant is operating at power as opposed to when it is in shutdown in the steam generator tubes?

A. Well again we are going to have to get into specific failure mechanisms here.

Q. Okay.

A. There are some cases where I would say that would be a true statement.

Q. Well for example, you would be more likely to have a tube damaged by a loose part rattling around in the steam generator when there was flow through it, wouldn't you?

A. Yes.

Q. And that would more generally occur in operations although it might occur during shutdown, isn't that true?

A. It would most likely be left in there during -- in other words, you would be most vulnerable after you had done some kind of work in the steam generator when the plant was shut down; therefore while you are increasing temperature, starting up flow, you may see more damage from that aspect.

Q During operation, after an cutage in which work was done on the steam generator?

A You may be more susceptible before you would turn critical or up to high temperatures, underin that mode, whereas corrosion may be higher at temperature.

Q Okay.

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The chemical -- if we may call them that -- corrosion mechanisms as opposed to physic_l damage from an object, do those tend to progress faster at higher temperatures?

A Some of them do, yes.

Q Okay.

Which ones do?

A I believe stress corrosion cracking, but I would have to get into the details of some of the affidavits that were filed earlier.

Q Okay.

Was that covered in your affidavit?

A No.

Q Okay.

But your knowledge is that you believe some go faster and some do not as you increase temperature, some of these chemical corrosion mechanisms?

A That's a variation, yes. I think the two compensate for each other.

Q That is you think there will always be some corrosion taking place, and some mechanisms will be more prominent at higher temperatures and some at lower?

A I think that would be a reasonable characterization.

Q Okay.

Do the cycling through temperatures having the plant come down and then start back up, the frequency of shutdowns, would that effect corrosion in any way in the steam generator tubes?

A I'm not aware of a direct link.

Q Okay.

But it is part of that process, is it not, that you would be -- when you take the plant off-line you would be bringing down the temperature and pressure in your steam generators and then, when you're starting back up, you would be raising the temperature and pressure in your steam generators as you get back up to power operation, would you not?

A Yes.

Q Okay.

And just to make sure I heard you right, you are saying you don't know what effect that would have, or are you saying that you don't think it would have any effect?

A Well, for a plant like Harris I don't feel it would have any effect. For a plant such as -- that is susceptible to heavy denting, there may be some correlation there.

Q When you say a plant like Harris, what characteristics of the plant are you talking about that distinguish it?

A I think the main one is the ABT chemistry, being on that from the start of commercial operation.

Q Okay.

A Also the very tight specifications we have with respect to allowance for copper and other impurities in the system.

Q Now the steam generators for the Harris plant were fabricated some time ago, were they not?

A Yes.

Q So their fabrication would be to the standards in effect at the time they were built, not the current standards, wouldn't they?

A They would, although you don't see-- There are some modifications that may be recommended at this point but not anything that we think would significantly change the results.

Q Well, what kinds of modifications are you talking about there?

A Things such as a quadrifoil support plate design would be an example.

Q Okay.

So if I take you correctly, what your judgment of this matter is that the main difference between Harris and some of these older plants as far as the effects of startup and shutdown is concerned is the water chemistry and the requirements for copper and so on in the system.

A Yes.

Q Okay.

Now in your data base, how much actual operating experience have you got with plants that are subject to those same requirements for water chemistry, copper, and so on, as Harris?

A All of the plants in the data base that have been operating for the last year to several years will be meeting those kinds of chemistry specs.

Other plants would have had significantly more -- I will call it "liberal" chemistry specs over what are being used at Harris.

Q Is that all you wanted to say about that?

A Yes.

Q Okay.

I wanted to back up and ask:

Do you know when these tighter chemistry specs first went into effect?

A You would have to look at specific plants as to which were operating. The tightest specs have come into play in the last couple of years.

Q Since 1982?

A '81, '82.

Q Okay.

A But there have been changes in the specs, in other words a tightening of the specifications, for the last ten years or so.

Q Various tightenings in other words?

A Yes, mainly because we were dealing with plants that had phosphate chemistry to begin with.

Q What percentage of-- Well, let me ask you this:

Of the plants in your various tables, can you identify which ones had phosphate chemistry?

A I can, yes.

Q Okay.

I'd be very interested in the proportion of tube years that plants have phosphate chemistry comprise of these data bases.

A Okay. I would have to provide you that, because I can call back to Pittsburgh or whatever to get the exact number as to what plants have never operated on phosphate chemistry and what plants have started at some point.

Q Do you think it would be possible to produce that sort of data today, or would we have to wait for it longer?

A I may be able to get you a rough number today.

Q I would appreciate it if you could.

Does your analysis of the number of tubes in these various tables take any account of the number of tubes which have been plugged, or the times that they were plugged in these plants with Inconel tubes in the steam generators?

A That's the reason for choosing the 10 percent reduction factor in the data base.

Q Okay.

Now that 10 percent reduction factor....

On page 5 of your testimony, Answer 8, that is where that reduction factor of 10 percent is stated, is it not?

A Yes.

Q Do you have that page in front of you?

A Yes, I do.

Q Okay.

Does it say anything about tube plugging or any other reason for the discounting of 10 percent on that page?

A No, we didn't, just that it is standard practice to discount this because it is common knowledge that we have had a number of tubes plugged in the past.

Q Okay.

What is the approximate percentage of tubes in these plants which are now plugged?

A I think it is 2.4 to 2.5 percent.

Q Okay.

And that is the percentage of all the tubes without taking into account what proportion of them are in plants that have been operating a long time and what proportion are in plants that have been operating for a short time?

A Yes, that's right.

Q Okay.

You say 10 percent is a standard discounting. Who sets that standard?

A Well, in this case I set the standard.

Q It is your judgment?

A Well, it is my judgment that I wanted to use a conservative upper bound in doing my calculations.

Q All right.

So is what you're saying that no more than 10 percent of these tubes will end up having to be plugged?

A No, that is not what I said. I said that the data here was discounted 10 percent to account for this kind of phenomena. The historical record, as I said, was about 2-1/2 percent or four million tube years of experience.

Q Now it is not 2-1/2 percent of the tube years, is it, or is it? Is it 2-1/2 percent of the tubes, or 2-1/2 percent of the tube years?

A It comes out to 2-1/2 percent of the tubes have been taken out.

Q Okay.

A And when you factor that back in it is still significantly less than 2-1/2 percent in terms of the tube years.

Q All right.

Now are you aware of any analysis of the probability of rupture of one of these tubes which had its wall thickness corroded 40 percent?

A I'm not sure if I understand the question.

Q Let me try to rephrase this.

You said before that there were on-going studies of the strength of the materials in the tubes, and various factors that would impact the criteria for when a tube needed to be plugged. Is that correct?

A Yes.

Q Okay.

Now is one of those factors the possibility or the probability of tube rupture?

A I'm searching for what the link is. Your question was....

Q There are analyses which you said are on-going as to the material properties of the tubes, and other factors which impact what criteria you use for when you have to plug a tube in one of these steam generators. Correct?

A There are studies that are done as part of our engineering process to verify the strength of the tubes even under severely degraded conditions.

Q Okay.

Have those tests included tests of pressure pulses or other phenomena which might rupture tubes performed on tubes with degraded wall thicknesses?

A Oh, numerous.

Q And are you familiar with the results of those studies?

A Yes. I have seen a number of those tests run. I have also seen the tubes where we have taken tubes and tied them into pretzel shapes and repressurzed them up to five or six thousand psi, even some up to ten thousand.

We have also milled defects into the tubes intentionally down to only 20 percent tube thickness and still demonstrated that we can withstand almost full pressures.

Q By "almost full pressure," what pressure do you mean?

A Again there is a whole spectrum of events. The ones I have seen, the tubes were still good up to five to six thousand psi even at the very severely degraded conditions.

Q Now were those new tubes or corroded tubes?

A Those were new tubes, but they had had design flaws milled into them; in other words, actually taking a grinding wheel and grinding away major portions of the material in different configurations, slits and other kind of things.

Q Cut into the tube with metal-working equipment?

A Cut into it, even lathed, where you actually cut all around the tube.

Q And how long would they be exposed to the pressures that you're talking about?

A Again the tests went anywhere from a few minutes to a fairly long timeframe. I would have to get into more detail or refresh my memory on what the tests were run at exactly.

Q Okay.

Well, to the extent that a tube held up for a few minutes, that does not necessarily mean it would hold up for days or years of operation in a reactor under those conditions, would it?

A I don't think you could make that statement. Once you have demonstrated that the tube maintains the static pressures and we've pumped significantly beyond the normal design pressures, we would still have a high confidence that we could pick up these faults in the next eddy current inspection or other process.

Q That is why you plug the tubes. Correct?

A Yes.

Q Now as the tubes-- Well, let me ask you this:

Were any of the tests that you're talking about here, or any similar tests performed on tubes or portions of tubes that had actually been in a steam generator and had been removed as part of a tube replacement or steam generator replacement?

A I believe some tests were run, but I'm not familiar with them.

Q Okay.

As a tube ages or is in a steam generator as time goes by and the plant operates, that tube is still subject to additional corrosion beyond whatever it may have experienced in the past, is it not?

A Some rate of corrosion.

Q Yes.

Can you tell me what the design life of the tubes themselves is? Is there a design life for them, how long they are supposed to be able to hold up against corrosion in these steam generators?

A Well, our design is for 40 years.

Q Okay.

In these numbers of tubes, for example, Table 1, I notice that some of these numbers recur a good bit. For example, the number 13,552 seems to appear at least seven times on page 14 I believe.

Do you have that in front of you?

A Yes, I do.

Q And it is correct that the number 13,552 tubes occurs seven or eight times on that page, isn't it?

A That's correct.

Q Okay.

And the number 10,164 occurs at least five times on that pages, does it not?

A Yes.

Q And the number 6,776 occurs three times for plants labeled E and O and P; does it not?

A Yes.

Q Okay. How many tubes does the Harris plant have?

A I forget the exact number. Let me look it up in my testimony.

13,734.

Q Is there any -- let's see. Harris is a three-loop plant, and I believe your testimony states there are 4,578 tubes per steam generator?

A I believe so, yes.

Q Okay. Do you know how many loops are in these plants in table 1; how many steam generators each has?

A I could find that out very quickly, if you need that. In general, the earlier ones are two-loop plants; the later ones are four-loop plants.

Q And the three-loops are mostly somewhere in the middle?

A Yes.

Q Excuse me a second. I need to flip here and find something.

(Pause.)

The number of tube years in all these tables is just the number of tubes times the number of years; isn't it?

A That's right.

Q Okay. And it wouldn't matter, for purposes of this analysis, whether the plant was shutdown all year or running at full power all year; would it?

A That's correct.

Q Okay. You didn't take any of that into account -- the operating level of the plant?

A That's right.

Q In the specifications that these plants themselves require, as opposed to -- let me ask you this. Is there an NRC regulation as to the water chemistry that's required in these steam generators?

A The recommendations that the utilities adhere to, yes.

Q There are recommendations. Are they formally put into the regulations?

A I believe they are. Again, I'd have to talk to someone about it, get that from someone else.

Q How often, if you know, do any of these plants that are listed in any of these tables, get outside the specifications for water chemistry which Westinghouse recommends.

A Currently there are slight variations or deviations. But, in general, most plants stay within the specs. There can be excursions for modern plants. I want to make that very clear as to what generation of plants we are talking about here.

Q Okay. Now, by the modern generation, what years of initial operation are you talking about; or is that your criterion for modern plants?

A Well, I'm just saying that plants since, approximately 1980 and that timeframe, started adhering very strictly to these kinds of chemistry specs.

Q And it would such strict adherence in order to make your analysis valid, wouldn't it?

A No it -- well -- the data that I used involved -- or a significant portion of the data I used -- involved plants that were not adhering to this kind of a tight spec. Therefore, there's a bias with respect to that kind of -- that portion of the analysis. In terms of improvement, from the historical data base, I expect the plants to adhere to those type of specs on a reasonable basis.

Q Now, the part of your analysis which has this bias, as you say it, for plants that did not necessarily adhere tightly to water chemistry specifications, that's the analysis where you take 4 million tube years, discount it 10 percent, and use a failure rate based on that and the number of observed failures; is it not?

A That's right.

Q As far as the physical properties of the tubes themselves are concerned, do you know if it has any effect on the ability of the metal to resist rupture, how many times the tube has been stressed to design pressure or above, and then brought back to a lower pressure or zero pressure?

A We have a series of calculations that's part of our design process. They're called design transients. We take into account these physicals, or these thermal stresses in heat up and cool downs. So there is that kind of a numbered factor into the selection of materials we plan on using.

Q In other words, there's a thermal stress and a pressure stress in most situations where you heat up a steam generator; is there not?

A Yes, and we also include design transients, as such, in terms of these kinds of pressure pulses that we would expect to be an upper bounds of what the equipment would endure over 40 years.

Q What about pulses of higher temperature, how does that take into account your analysis?

A Well, we always do the analysis in a linked fashion. In other words, we postulate accidents and then whatever the combination of pressure and temperatures that are induced are factored into the analysis. So, yes we do take both those into account.

Q These are analyses you're talking about. The question I originally meant to ask you -- let me try it again.

When you take a metal tube that's designed to resist pressure such as one of these steam generator tubes, and you subject it to some pressure and then you slack the pressure off, and then you cycle it through an increase of pressure and a decrease of pressure again, does that have any effect in straining the metal of the tube?

A I'm not aware of any effect that would be germaine for the number of cycles we're talking about in the condition you're postulating.

Q Well, how many cycles are we talking about, just up to design pressure and down, in the lifetime of one of these plants?

A I don't know the exact number. It's probably hundreds or thousands, rather thousands.

Q Are you sure what that number is?

A I don't know what the number is at this point.

Q Okay. Now, hundreds would correspond to a few times a year, over 40 years. And thousands would correspond to the tens of times per year, roughly speaking; yes?

A Yes. A thousand would be 25 times a year.

Q Over 40 years; right?

A Yes.

Q Okay. Now, the longer a plant operates, the more of these cycles of normal pressure coming on and coming off it would go through; correct?

A Yes.

Q Okay. So -- let me see if I can go through here -- The largest number of years of commercial operation that I find in any of your tables -- and please correct me if I'm wrong --

is the 15.4 years for plants A and B in table 1; is that correct?

A Yes, I believe so.

Q That is correct?

A Yes.

Q And the design life you're talking about is 40 years?

A Yes.

Q Okay. So that's less than half for the oldest plants, of the design life?

A Yes.

Q Now, if we attempted to -- well, let me just ask you this. Mathematically, it would be possible to figure out the number of tube years beyond a certain lifetime; would it not? In other words, if I wanted to know the numbe r of tube years for plants that had more than 10 years or -- the number of tube years for tubes that had been in commercial operation for more than 10 years, I could simply subtract 10 years from the years of commercial operation and not worry about any of the plants where the operation had been less than 10 years. And then I could take the years beyond 10 and multiple that by the number of tubes. And that would be my tube years above ten years of operation. And that's a mathematically calculable number; isn't it?

A Yes.

Q Okay. And if anyone did this, that would show the proportion of the tube years that were beyond a certain number of tube years of operation; wouldn't it?

A That's right.

Q Okay. And that could be done up to and including the maximum number of tube years shown in the table, but beyond that you couldn't say because you wouldn't have any actual experience beyond that; isn't that correct?

A That's right.

Q Okay. In the Westinghouse foreign plants in table 2, do you know if the -- first let me ask you: Do you know what country these plants are located in?

A I can get that number -- or that information.

Q Okay. Do you know if the regulatory bodies or laws of those nations impose any specific requirements on steam generator or water chemistry?

A There are requirements, I don't know what they are though.

Q Okay. Does Westinghouse require these plants to adhere to any specific water chemistry specifications?

A No, we make recommendations.

Q Okay. Is the same thing true in Japan, that you make recommendations?

A Yes.

Q Do you know if there is any specific requirements that the Japanese government or regulatory agencies may have for water chemistry for those plants?

A There are specific requirements, as in all countries. Again, I don't know the exact differences.

Q On the Framatome plants on table 4, one thing I notice is that every one of these plants has 10,164 tubes; is that correct?

A That's right.

Q Is that because they are all a standard design?

A Yes. All standard three loop plants.

Q Okay.

Do you know if any of these plants use ABT water chemistry?

A My understanding was that they all used ABT.

Q They have all used from the beginning of commercial operation?

A That's my understanding. I could verify that if you wish.

Q All right.

Now, what were the criteria whereby you decided that the various plants recorded in these tables should be included in your study of steam generator tube rupture?

A My criteria was not to exclude plants. My criteria was to not exclude plants. In other words, just say that I will take the data as it exists, recognizing that there's a wide spectrum of phenomena that's been experienced. We don't see any particular phenonema sticking out from one plant to another. And so therefore, my decision was not to exclude data, but the converse of saying I'll just include this as something else.

Q I'm sorry, I may have misspoken. I was meaning to ask you what your criteria were to include data in this. And is your answer to that that you included all the data there was?

A Every bit of data that we had our hands on. And we think that we have all the Westinghouse operating experience.

Q Okay. So that's all the Westinghouse plants that have Inconel steam generator tubes, are in these tables?

A Yes.

Q Okay.

A As of October -- exuse me, the middle of '83.

Q Now, of your tube ruptures as listed in table 7, four of these happened in the United States, did they not?

A That's right.

Q Okay. And we could construct a statistic for the U. S. Westinghouse plants as opposed to the worldwide Westinghouse plants by taking those four failures and applying to them the tube years of experience of the United States Westinghouse plants, discounted by 10 percent in the same manner that you have done for all plants, can we not?

A Yes, we could.

Q Okay.

Now you say"attributed cause" in the fourth column of that table. Did Westinghouse itself do analyses on the tubes that were ruptured in these plants?

A On some of them we did.

Q Do you know which ones?

A We have actually seen all of these. It just depends on what level of detail you want to talk about all these.

Q Now, by seeing, you mean you have had people actually look at the tubes themselves?

A Yes.

Q Okay.

I guess what I'm trying to get at is, how many of those did Westinghouse take back to their labs or other test facilities and examine there?

A I don't know the exact number. I know that for one of them specifically that it was brought back. The other ones, I do not have the data as to how many we physically had in our hands, so to speak, as opposed to going to the utility or to a laboratory to see them.

Q Okay.

Do you know which one it was that was brought back?

A That should have been number 1.

Q Number 1, plant E for 1975? Where do the data on attributed cause in this table come from?

A Westinghouse assessments and also NRC assessments.

WRB/pp 11

Q Is there any difference between the Westinghouse and NRC assessments on any of these, to your knowledge?

End 7

A Not to my knowledge.

8 fls.

#8 WRBwb1

Q. The NRC assessments, I would take it, come from the references listed at the bottom of that table; is that correct?

A. Yes,

Q. Where are the Westinghouse assessments documented?

A. Again, there are reports that have been issued to the utilities where this has happened. They are WCAPs.

Q. Any others?

A. Well, there is a direct response that we made in numerous hearings, or in other licensing arenas, as to what the phenomenon was. The transcripts of those also indicate our opinion as to what happened.

Q. Okay.

In Westinghouse's analysis of these causes, do you know how they go about determining a cause?

A. Not specifically.

Q. Okay.

JUDGE KELLEY: If this is a logical point, we might take another short break.

MR. EDDLEMAN: I'm going to, if I may, just go ahead and hand out a crossexamination exhibit. It is not an exhibit; I'm going to try to get it in the record.

JUDGE KELLEY: All right.

Is this a good place for a break?

MR. EDDLEMAN: Yes.

WRBwb2

JUDGE KELLEY: Okay. Ten minutes.

(Recess)

JUDGE KELLEY: We'll resume at this point, and then we'll break for lunch at twelve-thirty for about an hour, or right around in there.

THE WITNESS: May I make a point of clarification?

JUDGE KELLEY: Surely.

THE WITNESS: One question that came up was how many plants had had the steam generator replacement done. I answered that, consistent with my data base, through July of '83 that there were four plants that had had a replacement. If you would come up to October of '84 you would have to add in two additional plants. So, therefore, I answered that question in the context of the data that is inclosed in my testimony.

JUDGE KELLEY: Thank you.

BY MR. EDDLEMAN:

Q. Was the question asked in the context of your data?

A. That's what I thought.

Q. Well, the record will show what was asked, I guess.

Let me ask you this: What are those two plants?

A. One is Point Beach-1, and the other one is Robinson-2.

WRBwb3

Q Robinson-2 is a CP&L plant, isn't it?

A. That's correct.

Q Let me turn to page 4 of your prefiled testimony. Your answer No. 3 at the top of that page says you've been involved in developing probabilistic models to quantify the frequency of steam generator tube rupture, etc., since 1982.

The analyses that you have directed there, which of those are for three loop plants?

A. Specifically the Italian reference design is a three loop plant.

Q Okay.

Was that analysis done on the same basis as your analysis here?

A. Very similar, yes.

Q Okay. So the assessments and the probabilities and the like were done basically the same way that is laid out in this testimony?

A. A very similar methodology, yes.

Q Okay.

In Answer 5 you say,

"The Harris FSAR contains an analysis of a single double-ended rupture of a steam generator tube."

Just for clarity, what is a double-ended rupture of a tube?

WRBwrb4

A. What that means is that the tube essentially shears apart, and you would essentially have no flow restriction of the bending of the tubes, the crimping of the tubes, that you maintain the ovality of the tube from its pre-rupture condition.

In essence, what it means is that you guarantee the maximum possible flow rates achievable from its rupture.

Q. So if you just, say, sliced one directly across itself and pushed the ends apart, that would be a condition like this?

A. Yes.

Q. Okay.

Now, what is the flow amount that you get under that condition for the Harris plant?

A. It's approximately 800 to 900 gpm.

Q. Eight or nine hundred gallons per minute.

Did you get that number from the FSAR?

A. I have seen calculations. The only reason I gave you a spectrum was that it's based on the pressures of the plant across the -- from the primary to the secondary side. So it is a dynamic calculation that has to be done.

Q. All right. So it's around 800 or 900. And I didn't catch the source. Where do you get that spectrum?

A. That is from the FSAR calculations.

Q. Okay.

WRBwb5

Do you know of any other calculations of the flow rate from such a break?

A. None that would be any more than was used in the FSAR.

Q. All right.

In your Table 7, I believe that the highest flow rate shown there is about six or seven hundred -- 634 gallons per minute for Plant C.

A. Yes.

Q. That's Ginna, isn't it?

A. That's correct.

Q. That does come pretty close to eight or nine hundred?

A. Yes.

Q. Okay.

You say in your Answer No. 6, that the frequency of these events is judged to be less than once in forty years, or not expected to take place during the lifetime of the plant.

Is that the mean frequency of the event or the highest frequency that you would get with a 95 percent confidence level? How is that defined?

A. That's the mean value.

Q. That's the mean value.

So you're talking about a straight statistical

WRBwb6

expectation. It's less than one in forty years, and you multiply by forty years and you've got an expectation of less than one?

Let me split that into two questions.

Is that a straight statistical expectation?

A. Yes.

Q. Okay.

And is what that means that if your frequency expected -- your mean expectation of frequency is less than one in forty years, you multiply by forty years of operation and you expect less than one event?

A. Yes.

Q. Okay.

Now, that's not the same thing as an expectation of zero events in forty years, is it?

A. That's correct.

Q. Okay.

I'm trying to do two things at once here, and I'm having a little trouble. Excuse me.

(Pause.)

The expectations and values in here are all derived from the experience-- Pardon me.

When you refer to historical experience in your testimony, as in Answer 7 on page 5, what you're talking about there is the experience as documented in your Tables

1 through 5, is it not?

A. That's right.

MR. EDDLEMAN: Excuse me just a second.

(Pause.)

BY MR. EDDLEMAN: In the FSAR analyses, as you refer in your Answer 9, those analyses give consequences of the rupture events as well as probabilities, do they not?

A. Yes, they do.

Q. How would you compare the consequences of the Ginna event?

A. Let me clarify that. The FSAR gives consequences of the event, not necessarily exact probabilities.

Q. Yes.

In other words, what you're saying is, you can give a probability of an event but you're not calculating an exact probability of the consequence, you're calculating a conservative consequence?

A. No. The FSAR groups events into categories. One of those categories is, as I described it in my testimony, for tube rupture events not expected to occur during the plant life.

Q. And that's those with an expectation mean value of less than 1 in 40 years?

A. That could be an interpretation, yes.

Q. Well, that is a correct interpretation, isn't it?

WRBwb8

A. Yes.

Q. What I wanted to ask you before: How would you compare the consequences of a Ginna rupture event with the consequences that are calculated in the FSAR for that event?

A. The FSAR event is much worse, or bounds the calculation by a significant margin, or from what the actual results were in terms of the health consequences.

Q. Well, isn't there an assumption in the FSAR analysis that these events would be brought under control in thirty minutes?

A. That's one of the assumptions, yes.

Q. And that assumption did not prove true at Ginna, did it?

A. That's correct.

Q. Okay.

Now, in terms of health consequences of the Ginna event, are you an expert in radiological health effects?

A. No, I am not.

Q. Did you read some analyses of health consequences at Ginna?

A. Yes, I have.

Q. And what you're saying is, your reading of that is that the consequences of the actual event, as stated by whoever wrote this analysis, is less than what the FSAR event--

A. My reading of it, and also relying on expert opinion within Westinghouse as to what the consequences were, consistent with my statement.

Q. All right.

Let me refer to your appendix, Attachment A, the pressure pulse model, if I may. I believe that begins on page 23, as your pages are numbered.

A. Yes.

Q. Okay .

In the second paragraph there, the first sentence says,

> "The 6 x 10 to the -7 per tube-year rupture frequency calculated from the modified experience base is the frequency of degradation to the extent of rupture under the normal operation tube differential pressure load in the range of 1250 psi."

What I want to explore with you a little bit is what that sentence means.

Does this frequency refer to ruptures under a differential pressure of 1250 pounds per square inch?

A. Yes.

Q. Okay.

A. Conversely, what that means is that the only tube ruptures that we have ever experienced to date have

WRBwb10

occurred under those conditions.

Q That is under a pressure of 1250 psi or less across the tube?

A Yes.

Q Okay.

Now, it says the frequency of degradation to the extent of rupture under those conditions. I take it that means that the tube degrades to the point where it will rupture under those conditions.

MR. O'NEILL: Excuse me; I didn't understand the question: the antecedent for "under those conditions."

MR. EDDLEMAN: Okay.

BY MR. EDDLEMAN:

Q This says that the 6 x 10 to the -7 is the frequency of degradation to the extent of rupture. "Under those conditions" means the normal operational tube differential pressure lies in the range of 1250 psi. That's what I meant to ask.

A Yes, that's right.

Q Okay.

Now it says that the model assumes that for a tube that does degrade to this extent, it may take anywhere from zero to forty years of operation with equal probability.

That's an assumption that you make; right?

A Yes.

WRBwb11

Q Okay.

Now, what does the differential of 1500 psi that is listed in that third paragraph come from?

A. That is the maximum differential that we would calculate if we had a pressure surge in the primary coolant loop. In other words, we start to heat up the primary system due to an accident, and we had to relieve steam through our safety valves.

Q And so the 2500 pounds per square inch is where the safety valves should lift? --should start to relieve pressure at that point?

A. Yes.

Q Okay.

Now, then, for a differential to be 1500 under those conditions, that would assume 1000 pounds on the secondary side?

A. Yes.

Q Is it possible to get the primary side up in the range of 2500 with the secondary side pressure lower than 1000 psi?

A. Yes.

Q So you could, in fact, get the differential pressure higher than 1500 under some conditions?

A. Yes,you could. The system under a steam break condition could be up to 2500 psi pressure differential.

WRBwbl2

Q. Okay. So it could be 2500 on the primary side and zero on the secondary side?

A. Yes.

Q Is it possible for that 2500 psi safety valve to fail to actuate at its set point?

A It's possible. It is an extremely rare event for all safety valves to have failed.

Q How many of those safety valves are there? Are there more than one?

A Well there's more than that. There are power operated relief valves that would be challenged first to the limit pressure to less than 2350 in pressure. If those don't open then you are challenging the safetys. Typical designs have two to three safety valves.

Q Okay.

In this model that is given down at the bottom of that page and it says it is shown in Figure A-1, which I believe is following page 26 at the last page of this prepared testimony, the time that this tube spends above 1250 psi but less than 1500 psi differential pressure, that is the numerator on the right-hand side of your equation on page 23, right?

A Yes.

Q Okay.

So by assumption that numerator is going to be 250 pounds if you just limit the differential to 1500.

MR. O'NEILL:

Say that again please, Mr. Eddleman, I think you misspoke.

BY MR. EDELMAN:

Q. By assumptions that you have made above that difference which is the numerator there is going to be limited to 250 pounds, if you limit the differential pressure to 1500 pounds per square inch; isn't it?

A. Well, the numerator -- that's correct.

Q. Okay.

Now, the term LI in the denominator there that's the minimum pressure at which a new tube would burst. And I believe you give that on the next page at 10,000 pounds per square inch?

A. That's correct.

Q. Okay.

And the L sub no is still the psi capability for normal operating conditions, which is 1250 psi?

A. That's right.

Q. Okay.

So this fraction here, if we looked at figure A-1, corresponds, does it not, to the area that is above the dashed line of L and O, the normal operating load and below the dashed line at LT.

A. Yes.

Q. Okay.

Now I see a T star, which appears slightly above the bottom of that graph on figure A-1. And a little back to the left of the letter T. Now T is the years of service; correct?

A. Yes.

Q. Okay. And is that T star there referring to the time between the vertical dashed line that comes down to the bottom of the graph and the solid line at time T?

A. Yes.

Q. Okay.

Now, to the extent that the transient load increases, that would raise the height on this chart at which the LT dashed line goes across to the sloping solid line of degradation; would it not?

A. Yes.

Q. And if you did the chart the same way with a higher LT, then when you got over to the solid diagonal line you would come down with a dotted vertical line showing a larger T star; wouldn't you?

A. Yes.

Q. And you could compute for any given LT off of this chart, what the T star would be?

A. That's correct.

Q. Now, in your calculation on page 24, the fraction of T the T star turns out to be, is 1 over 35; isn't it?

A. Yes.

Q. Okay. Now it says in the paragraph immediately below that that this model does not presume a great level of detail regarding the shape of the tube degradation curve. Now that degradation curve represents the lowering of the first failure strength of the tube, doesn't it?

A. Yes.

Q. In actual steam generator environments, do you know whether that curve is linear or not?

A. We've seen some variations from plants but, in general we haven't seen a wide variation between tube inspections.

Q. Do you actually test tubes removed from actual operating plants-- Inconel steam generator tubes I'm talking about -- for their bursting strength?

A. I mentioned earlier that I was aware of some tests being done, but not specifics.

Q. Okay. All right now, down at the bottom of -- well, let me ask you one other thing to tie that up: If the shape of the degradation curve were other than linear, you could go back to your figure A-1 and replace that diagonal slope, which is a uniform degradation rate labeled land on that, with the actual shape of a degradation curve and still find your T star from your load LT, the transient load, in the same way, couldn't you? That is to put a horizontal line across from LT to the curve, whatever it was, then come down vertically from that to the bottom?

A. Yes.

Q. And the difference of where you came to the bottom and T is the T star?

A. Yes.

Q. Now, it says "The weighted average of T star is calculated using the value of 0.59." And I believe the calculation of that weighted average is shown on pages 25 and 26; is that right?

A. That's correct.

Q. Okay. Now, it says, "The probability of distribution was assigned as follows: The five plants which have had tube rupture events make up about 10 percent of the tube experience base. In the experience rupture frequency for these worst plants is then given over on page 26 as one and a half events per 3.6 times ten to the fifth tube years.

Now, I take it you get the 3.6 times ten to the fifth by just taking 10 percent of your 3.6 times ten to the sixth experience base that you refer to earlier; is that correct?

A. That's correct.

Q. Where does the one and a half come from?

A. Well, I've alluded to what figures of merit were achievable, in terms of modifications to the way modern plants are operated versus what the experience base had shown five, ten years ago. And so those are discussed in my response to several of the questions.

Q. All right. So this isn't a straight experience base

It's adjusted from 5 to 1.5, isn't it?

A. It's not straight experience, but the modifications of the numbers are based on the trends that we have experienced over the last five years.

Q. Well now, let me try to -- let's -- your answer on page 14 describes that analysis or judgment that you made to get the 1.5 number; does it not? Page 10?

A. Oh, yes.

Q. Okay. Let me leave that there and come back to it later. I just want to go through this probability calculation.

So you adjust your worst plants in accord with these adjustments you make in that answer and that gives you your high side 10 percent probability for the worst plants. And then the median that you calculate is assigned a probability of 80 percent, okay?

Now, where is it that you calculate that median?

A It's from the Ki [illegible] square tables, assuming an upper bound of 90 for my first calculation.

Q. Assuming an upper bound of 90 percent on the --

A. Wait a minute. I'm mistaken on that. That median value is just using the entire data base as part of our distribution. In other words, we concentrated the data for the upper bound number, for the five plants that had experienced the tube ruptures, and then when we did the calculation for the medians we essentially took the five or took all of our data and used that in the base.

Q. And then the lower table from the Chisquare table was assigned 10 percent. Now that's basically using the Chi square to make a confidence level pattern around this -- or distribution around this median, right?

A. Yes.

Q. Okay. And when you do that, you took the lower table to be what confidence level?

A. The lower was 5 percent.

Q. Okay. So you assigned the lower 5 percent a 10 percent probability?

A. Yes. We assumed that the value was valid over the zero to 10 percent range.

Q. Okay. Now, if I've got this right, what you assumed was that the level at which you're confident no more than 5 percent of the data falls below, you assigned it the average from the range of the lowest zero to 10 percent of the data?

A. Yes.

Q. Which essentially assumes some kind of uniformity in the way that data falls off?

A. Yes, within those tables, yes.

Q. Do you know if that's an accurate assumption?

A. At those kind of confidence levels, yes, the values tend to be linear.

Q. Okay. Now, let me back up a little bit.

On page 25, when you discuss the weighted average of T star, where do you calculate that weighted average?

A. You're saying T star from page 25?

Q. Yes. You say, "The weighted average of T star is calculated yielding a value of 0.59."?

MR. O'NEILL: That's on page 24, Mr. Edelman.

MR. EDELMAN: That's right, I'm reading from page 24 and I'm asking for where do you calculate the 0.59?

A. I thought I understood you to say you were on page 25.

Q. I'm sorry. I'm on page 24, at the very bottom, that very bottom sentence and equations?

A. That calculation is not part of this testimony, in the supporting calculation.

Q. Can you tell me how that calculation is made?

A. I'd have to refresh my memory as to the exact coefficients.

Q. Is it made on a confidence interval?

A. There are confidence intervals that are calculated in the coefficients. Again, I need to get into the specifics of the calculation.

Q. Okay. However you calculate tha. weighted average, you then go over on page 25 immediately following that equation and you say, "The transient pressure differential is applied to all three steam generators. Based on this and the assumption that each tube's failure probability is random and independent, the probability of various numbers of tubes rupturing can be evaluated from the binomial distribution."

Now, the P that's used in that binomial equation is the same P that you calculated on page 24 as .59 lambda, does it not?

A. Yes.

Q. Now, it would seem that each tube's failure probability is random and independent. Wouldn't it be possible or even likely that if one of them failed, similar cause would be acting on other tubes in the same steam generator?

A. Other tubes would be degrading in the steam generator, it's true. But from the standpoint of -- that doesn't mean that it is only applied to one tube at a time. We're saying that the tubes -- meaning all 13,000 tubes -- could be degrading. In fact, we are using the lambda on all the tubes. But each tube itself has a finite probability of being within one of these degraded conditions, which our tube plugging experience and our inspection experience states that the tubes themselves don't all suddenly come down together. There is a distribution to some tubes based on their locations in the steam generators and to be more vulnerable.

And so each tube is not being acted upon and having induced the same degradations, identical, so that we don't see a whole degradation of the tube bundle at the same time.

That's what our eddy current inspection testing is based on, is picking up these outwires that are coming down into this zone of vulnerability.

Q. All right. But in the distribution of tubes degrading, some will be pretty close to the most degraded one, won't they?

A. Yes.

Q. Okay. And, isn't it true, as you say below that --excuse me. Let me turn to another matter first.

You said that you do inspection on the tubes to try to pick this up and you have frequencies where you find degradations. Did those percentage of tubes degrading play any role in this analysis that is reported here in your appendix?

A. Well, that's one reason why we provided the bias that I mentioned toward the five plants that had seen what I will call a more severe degradation.

Q. And that bias is the selection of 10 percent in the weighting that occurs back towards the end of this appendix?

A. Right. In other words, skewing our distribution towards those.

Q. Okay.

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You then also make an adjustment from 5 to 1.5, the number of events that you attribute to that group, do you not?

A. Yes we do.

Q. Okay.

Now, you say later on here that these components have identical probability distributions. The tubes themselves are not identical, are they?

A. That's right.

End 9

10 fls.

Q In particular you said earlier that some of them were in positions that make them more vulnerable to degradation.

A The tubes themselves are identical. As I mentioned before, the tubes may be susceptible to different types of phenomena, depending on location and other issues.

Q Okay.

In assuming that they have identical probability distribution functions or PDFs, aren't you in effect assuming that that averages out over all the tubes? That is, if one is more likely to fail for one reason, that the other one over here has got to be more likely to fail for another reason to have an identical probability distribution?

A Yes.

Q Okay.

And that isn't really true, is it?

A There is a-- Yes, you must be careful when you're using those kinds of assumptions. Now let me clarify one point here in what the pulse model is trying to do, or does.

What the pulse model does is to identify the maximum numbers of tubes which may be in the degraded pressure resistance window such that if you had a pressure pulse that occurred you would have the maximum number of tubes that were -- I'll call it near the limit.

So therefore from the standpoint of the analysis, we want to make assumptions which maximize the potential for

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those kinds of conditions occurring.

If you assumed a very skewed -- well, not skewed but non-uniform tube degradation rate, what happens is that you tend to increase the frequency of single tube rupture events which means that a tube fails much sooner, but when it fails, you also do your inspections and pick up these other failure mechanisms.

So what happens when you do sensitivity studies on this kind of a calculation, you find out that you have -- you are actually reducing the number of tubes that may be vulnerable to generating multiple tube rupture kind of events.

So my answer is that it is true that you must be careful when you make the assumption of linearity, be there may be a non-conservatism with respect to one pa your prediction process. That's why we lean very heavily the single tube rupture frequencies and use an historical data base.

From the standpoint of the multiple tube rupture which is really the issue here, we feel that we have bounded that condition in those assumptions.

Q Well, to take into account what you just said about the assumptions, if you did have a smaller number of tubes with a failure rate that you calculated some other valid way, you could apply the same binomial distribution to them, simply substituting the number of vulnerable tubes for the total number of tubes, couldn't you?

A You could, yes.

Q Now when you get your 7 times 10 to the minus 5 number on page 26 for multiple tube rupture frequency, is that calculated directly from the binomial distribution that is shown on page 25?

A Yes.

Q Okay.

And how, if at all, does the probability distribution of lambda that is given from the last paragraph of page 25 over through the first table on page 26 enter into that?

A What we're using are the degradation rates directly on this table. We talk about the rate at which tubes can fail or degrade, rather. Excuse me.

Q So what you would do is to sum 10 percent times the calculation made with a lambda of 4.2 times 10 to the minus 6, plus .8 times the calculation made with a lambda of 6.0 times 10 to the minus 7, plus .1 times the calculation made with a lambda of 1.6 times 10 to the minus 7. Is that how you did it?

A No. What we end up with is a 95 percent confidence lambda. That lambda becomes the key to doing our calculations through the binomial equation.

Q Well, where does it say in this appendix that you are using a 95 percent confidence lambda in that calculation?

A That is what the probability density equation states.

Q Well, now, the probability density that you did was an assigned probability distribution. Isn't that what the bottom paragraph on page 25 says, as it continues over on page 26?

A Yes.

Q Okay.

And that was assigned by taking the five actual experienced events and reducing them to 1.5. Right?

A Yes, we assigned that, but we assigned it with the knowledge that if we had gone back and used chi-square which is just straight data that the number would be less limiting.

Q Well, what is the number that you get if you just use the chi-square?

A I don't think it is in my testimony.

Q Do you know what it is?

A I have the number calculated. I don't have it with me.

Q Okay.

MR. EDDLEMAN: I'm about done with this part. This would be a good time to take our break.

JUDGE KELLEY: All right.

We will take a lunch break until 1:30.

(Whereupon, at 12:30 p.m., the hearing in the above-entitled matter was recessed to reconvene at 1:30 p.m. the same day.)

GB 10 fls.

AFTERNOON SESSION

(1:30 p.m.)

JUDGE KELLEY: We can go back on the record at this point.

Whereupon,

MICHAEL J. HITCHLER

resumed the stand and, having been previously duly sworn, was examined and testified further as follows:

JUDGE KELLEY: I might just mentioned that for orientation purposes I asked Mr. Eddleman approximately where he stood with this witness. We are approximately two-thirds of the way down the road.

But you go ahead.

MR. EDDLEMAN: Thank you, sir.

CROSS-EXAMINATION (Continued)

BY MR. EDDLEMAN:

Q If I might, I would like to start off by referring you to this document that I just handed out which is a single sheet which has the notation at the top 550.4-4, and it is a chart, is it not, of the break flow rate in pounds per second versus time in seconds.

What I would like to do, with your Counsel's permission, is to show you the document that this comes from.

(Document handed to the witness.)

See if that looks the same as the page that I have reproduced except this part of the letterhead on the front got picked up on it.

A Yes, it does.

Q Now the front of this document on Carolina Power and Light letterhead gives the notation H-X-507 at the top, does it not?

A Yes, it is handwritten.

Q And down here at the bottom in the right-hand corner there is the number 000816 stampe d on it.

A Yes.

Q ANd if you will just look at the letter on the front of it, it is a transmittal letter, and the first sentence:

"For responses to the Final Safety Analysis Report, safety review questions to Mr. Harold Denton of the NRC...."

is it not?

A Yes.

Q Okay.

And this page that I have shown you of Exhibit 4-4, if we go back to numbers, the 50.4-3-2, and then we come to Question 50-4 at the top of the page, the page previous to that, do we not?

A Yes.

Q And it says this is about Applicants' steam generator tube rupture analysis, doesn't it?

A Yes.

Q And it asks for tables in the first paragraph here, including sequence of events as a function of time for the steam generator tube rupture, does it not?

A Yes.

Q Okay.

Now we have discussed before lunch the flow rates in these steam generator tube ruptures for FSAR analysis, hadn't we? Didn't we discuss that before lunch?

A Yes, as I recall, you asked for what was a typical peak flow rate for a single tube rupture.

Q You said eight hundred to nine hundred gallons a minute.

A Yes.

Q Now the pipe flow rate that is given in this figure here, which is labeled Figure 1, break flow rate, is in pounds per second, is it not?

A Yes, it is.

Q At time 0.0 in seconds it shows approximately 55 pounds per second, doesn't it?

A Yes.

Q And it then drops down to about 40 pounds per second, it rises back up to nearly 55, and then drops down to about 35, and then rises, finally smoothing out at about somewhat under 70, doesn't it?

A That's correct.

Q Now can we convert pounds per second into gallons per minute by calculation?

A Yes.

Q And one way of doing that would be to multiply pounds per second by 60 and then you would have pounds per minute, would you not?

A Yes.

Q And then divide by the number of pounds in a gallon. Right?

A Yes.

Q Do you happen to know how many pounds are in a gallon?

A It depends on what temperature you are specifying.

Q Under the temperatures and pressures that primary coolant would erupt at, do you happen to know how many pounds there are in a gallon?

A Not off the top of my head. A calculation could be done fairly easily.

Q Would you accept that it is somewhere in the range of eight to ten pounds?

A In that range, yes.

Q Now if we then applied that to say 70 pounds per second, that would be 4200 pounds per minute, wouldn't it?

A Yes.

Q And if we then divided that by eight, that would be about 525 pounds per minute, and if we divided by ten, that would be about 420 gallons per minute, would it not?

A In that range.

Q Okay. I think that is all I have on that line.

I would like to ask you about the Ginna break that I believe is in your Table 7, Plant Number C, I believe it is the fifth in the list of ruptures.

JUDGE KELLEY: Which table is that?

MR. EDDLEMAN: Table 7, Judge, page 21.

JUDGE KELLEY: Thank you.

BY MR. EDDLEMAN:

Q The break that occurred at Ginna, was that a double-ended break of the type that you analyze for an FSAR?

A Approximately, yes.

Q Approximately?

A In other words, there was a break of the tube but it wasn't necessarily a clean break that caused the maximum possible flows that could be achieved.

Q In fact that tube was split open for some distance, was it not?

A Yes.

Q So that the actual area that was open for coolant to flow out was larger than the diameter of the tube at the point of the break, but still you had the tube before that on your way back to the source of coolant?

A Yes.

Q So in effect it was just about as bad as having the tube broken off cleanly.

A Yes.

Q And that shows an estimated leak rate of 634 gallons per minute, did it not?

A Yes, it does.

Q Do you happen to know what the differential pressure between the primary and secondary sides were at the time of that accident?

A And operating pressure differentials?

Q About 1,000 pounds.

A It would be over 1,000.

Q Over 1,000 but less than 1,250?

A About 1,250.

Q About 1,250. Okay.

Are you saying that because that is standard or because you have reviewed it and remembered that that is the case?

A The reason why I'm hedging is that plants can be operating their secondary steam supply system at different pressures than the as-designed point, maybe a lower, maybe a little higher, depending on a number of characteristics.

Q So in fact the secondary side pressure can vary, can it not?

A Yes.

Q I think we covered most of that earlier.

Do you know the types of breaks that occurred for the other ruptures that are listed in this Table 7, the first four?

A None of the four were any kind of shearing. They were all split-type phenomenon.

Q And can we infer from their lower leak rates that they were rather less severe than this Ginna event that is the fifth one?

A Yes.

Q Let me turn for a second to the information I was asking you about before lunch. Were you able to get any of that information?

A Which parts of it? What I had mentioned was that I could give you a rough percentage as to how many plants were on a phosphate chemistry.

Q Yes, I wanted that. And I also-- Did you get that information?

A Yes.

Q What is that percentage?

A It is approximately 30 percent.

Q That's 30 percent of the tube areas?

A Yes-- 30 percent of the plants. Excuse me.

(Pause.)

Q I'm trying to find whatever the other thing I asked you about was.

The upgrades of the tube inspection programs, do you know what approximate dates those happened?

A No, I don't have that.

Q Let me ask you this:

As to independent probabilities, have there been instances where a part of a tube itself broke loose in a tube rupture event?

A None which caused a tube rupture accident.

Q Okay.

Would it be possible for one tube to rupture and whip around and break other tubes?

A It's possible; very improbable.

Q Whatever the probability is, is that taken into account in any way when you say the probabilities of tube ruptures are identical for the tubes?

A It is not taken into account explicitly in the models, no.

Q Let's turn if we may to the thicker exhibit that I handed out before the last break before lunch.

This I represent to you is a xeroxed copy of a chapter on "Probability and Statistics," the chapter concerning the Poisson Distribution.

Is the failure probability that we've been talking about here for the steam generator tubes a Poisson variable?

A It could be defined as that, yes.

Q And how would you define a Poisson variable?

A A Poisson variable tends to be -- is applied to a situation where you have a large amount of data usually with a small number of failures attached to the overall distribution.

Q It is often used for infrequent events in the sense that they don't happen every day. Right?

A It is used in that area.

Q Let me ask you if you've ever heard of a study of probability of a Poisson variable, namely the number of deaths caused in the German Army by being kicked in the head by a mule. Have you ever heard of a study like that, or a study of probability?

A I have heard people allude to that study, yes.

End 10

Q Okay.

JUDGE KELLEY: Which war?

MR. EDDLEMAN: They actually studied several hundred years, Judge, and there were a number of wars in there.

JUDGE KELLEY: Maybe the great war.

BY MR. EDDLEMAN:

Q Have you had a chance to look over this chapter that I passed out?

A. I haven't studied it to see what's in there.

Q Well let me ask you a few things about it, if I may.

The Poisson distribution is given as Equation 11.1 on page 109 of that copy, is it not?

A. Yes.

Q Okay.

And let me back up with you, if we may, to the examples of a Poisson distribution being given in Section 11.2 which goes from page 108 to 109. They are on the same sheet here.

This distribution has to do with -- Let me ask you, what is a sigma squared, that symbol that you used in the last equation on page 108. Are you familiar with that symbol as a statistical symbol?

A. In standard deviations and variances.

MR. O'NEILL: Mr. Chairman, I have some concern about what the record is going to look like on this cross-examination. This is not an exhibit, it is not evidence; to talk about what equation appears at 11.1 is not going to be particularly helpful in reviewing the record.

I suggest that if Mr. Eddleman desires to ask about an equation that he make it very clear in the record what he is talking about.

MR. EDDLEMAN: Okay, I will try to do that. In this case I just wanted to know what a sigma squared was.

BY MR. EDDLEMAN:

Q Now the Equation 11.1 that I referred you to before, the P in that stands for probability, does it not?

A Yes.

Q Okay.

And that probability is given as M to the R power, E to the minus M, product divided by R factorial, is it not?

A Yes.

Q And I believe you agreed that that was the equation of the Poisson distribution.

A Yes.

Q Now I refer you to the sentence that reads immediately above that equation, it says that:

"It seems obvious from this example...," that is N, which is the number of samples -- number of population that you could sample from, "...becomes indefinitely large so that P...," which is the probability, "...becomes small, "...then sigma T squared approaches Mu t."

Now in that statement Mu t is a mean, is it not?

A. I believe so, yes.

Q. It then says that:

"This is characteristic of the Poisson distribution...."

Now do you think it is a reasonable interpretation of that to say that the standard deviation in a large sample with a Poisson distribution comes pretty close to the mean of the distribution?

A. It could but again you have to get down to specifics as to what size data base you are really going to be using here, so it is difficult -- it could be misleading in talking about these kinds of generalities.

Q. Now in the example given above there they have a sample with 10,000 objects in it of which five they characterize as red marbles. Let's say they are the events of interest.

In other words, if we had a sample of 10,000 tubes and there were five failures, that would be equivalent to this example, would it not?

A. Yes, it could be.

Q. And it shows that the mean equals five, as you would expect, and the standard deviation is 4.9975, doesn't it?

A. Yes.

Q. Does that appear to you to be correct?

A. I will assume so, coming from a textbook.

Q. Okay.

4.9975 is real close to five, isn't it?

A. Yes.

Q. And isn't it true as you go through the examples there and increase the size of your sample that the standard deviation comes ever closer to the mean?

A. Yes.

Q. Okay.

Now if you have a standard deviation that equals the mean approximately you could say, could you not, that one standard deviation range to either side of the mean would go from zero to twice the mean?

A. In this example, yes.

Q. Okay.

I'm just trying to identify what the next part I want to ask about is, if you will bear with me for a moment.

(Pause.)

Let me ask you to refer to page 111 of this copy, down at the bottom of that page, which is Section 11.5, "The Expected Value of T for the Poisson Distribution."

Now the probability equation that is given down there at the very bottom of the page for P, the probability under the Poisson distribution, that is the same equation given in 11.1 that I referred you to earlier, is it not?

A. Yes.

Q. Okay.

And it then gives an equation for calculating the mean of occurrences of this variable in terms of that probability distribution, the first equation on page 112, doesn't it?

I'm sorry, that goes over a page division.

A. Yes.

Q. And it is simply the sum of the probability of a given number of events of interest, called R, times the probability of each such event, isn't it?

A. Yes.

Q. And this is summed from zero to infinity, in other words over an infinitely large distribution, isn't it?

A Yes.

Q So in the case of an extremely large or infinite distribution this equation would hold, wouldn't it?

A Yes.

Q Okay.

Now are you familiar enough with the series expansion of the number E to validate whether the method they go through showing that that --

A I want to be careful there in terms of how we said that we approached this number, because the other assumption that was in the basic equation was the number of failures that we have seen in our trials.

Q Right. I haven't got around to that yet.

A All right.

Q Okay.

Now the probability equation that it gives there is then spelled out as a series in the next equation, is it not, where it actually shows what the probability would be if R is zero and it adds to that the probablity for R equals 1 and R equals 2 and 3 and 4 and shows an infinite series of those probabilities, doesn't it?

A Yes.

Q And it then regroups the series so that you have the expression "M e to the minus M" times an infinite series of 1 plus M plus M-squared over two factorial plus M-cubed over three factorial plus as follows, which I take to mean as M to the nth over N factorial as the nth term, would you agree with that?

A. Yes.

Q. And it says that: "The limit of the sum within the parentheses is e to the m...," would you agree with that?

A. Yes.

Q. Okay.

So then the mean equals M times e to the minus M times e to the M, and since e minus M times e to the M is one, the mean is M, is it not?

A. I think so, yes.

Q. And that is what equation 11.6 shows, isn't it?

A. Yes.

Q. Do you see any problems with that derivation?

A. I don't think so.

Q. Now I don't think I want to go through the next section on the variance in that much detail, but doesn't it show in Equation 11.7 that the variance of T is also M?

A. Yes.

Q. Okay.

So when you've got a very large sample, in this case an infinite sample, the variance and the mean are exactly the same thing, aren't they, the same number?

A. Essentially, yes, with this derivation.

Q. All right.

Are you aware of other variations with a statistical variance of a Poisson distribution that give other results than this?

A. Not specifically at this point. I don't recall any of the specific variations that -- or the derivations we may have had in school.

Q. Now you use in your appendix a binomial distribution, do you not?

A. Yes.

Q. And in Section 11.7 here, it describes a binomial distribution as follows:

If P, the probability, equals M, the number of events, divided by N, the number of possibilities that you sample, then the exact probabilities associated with the possible values will be given by the expression parentheses P plus Q, close parentheses, to the nth power equals -- and then it gives a rearrangement of variables so that you come out with M over N in brackets -- you've got brackets and then you've got M over N plus the quantity in parentheses: one minus M over N, close parentheses, and then close the bracket around that and everything in the bracket raised to the nth power.

agb/agb9

Is that the binomial distribution that you used in your appendix?

A. Yes.

Q. Okay.

For the variance there it gives an equation, does it not, sigma squared of T equals N times P times Q equals N times M over N times the quantity in parentheses: one minus M over N, close parentheses.

It gives that equation, doesn't it?

A. Yes.

Q. And then it shows that:

"If N is large relative to M...," that is, N is a very large number and M is some fixed number,

"...then one minus M over N is approximately one...," and therefore sigma squared of T will be equal to "M times M over N," so the N's cancel out and it is approximately equal to M.

That's what it says, isn't it?

A. Yes.

Q. Now again are you aware of any interpretations of binomial distribution that would indicate that the mean is different than is given in these equations?

A. No.

Q. All right.

(Pause.)

end#11

AGB/pp 1

Tape 12

I want to come back to you now, to the question of assigning these probabilities. If we want to construct a poisson model of the rupture of tubes in Westinghouse steam generators with Inconel tubes, could we not take the number of ruptures experienced as our M number of events of interest in the universe of tube years as the space that we're sampling?

A. Yes, we could. That's one way to do it.

Q. All right. And does that differ from your analysis?

A. Yes, it would.

Q. How does it differ?

A. In other words, you can choose to use poisson distributions or these other distributions at different points in your quantification process. In other words, I can assume degradation rates on the single tubes, fit that to our poisson or chi square tables, come up with different confidence bounds. I can do the process there and pack it into a binomial distribution, the binomial process that I talk about here, or we would use a process similar to what has just been alluded to, strictly use poisson. I feel that the binomial usage has a lot more flexibility with respect to a phenomenon that we are discussing here. In other words, the poission distributions would not be able to deal with linked phenomona such as pressure pulses and other things such as this. So that has to be balanced as to where we want to apply these kinds of distributions and what part of the model we wish to use in predicting degradation rates or other types of failure mechanisms.

Q. Well, now, in regard to that answer, the poisson distribution in and of itself, simply concerns the number of events and interest and the considerably larger sample space in which those events occur, doesn't it?

A. Yes, it does.

Q. Now, when you make your analysis of tube failure rates and so on, the shape of the degradation curve doesn't have anything to do with the probability distribution function of the failures themselves, does it?

A. To some extent it does, because we are dealing with the point estimate, in other words, our five failures that we're imposing in the model. We want to have an idea as to what our confidence limits are and how the distributions change. We are dealing -- in the testimony, I discuss 5 percent and 95 percent confidence bounds, so that can have an impact when we're dealing with just a point condition.

Q. Okay. But you can get a confidence limit out of a poisson distribution too, can't you?

A. Yes, you can.

Q. And let me ask you a little bit about the chi square distribution. Can you define for me what a chi square distribution is?

A. Chi square distribution is -- in fact, in a lot of cases,it's called a chi square test -- because it's a measure of how well your data fits your predictions. In other words, once we have a set of data, we can use the chi square distribution to define what confidence levels we would be able to define acceptable levels.

Q. Now, the chi square is defined in terms of a number of degrees of freedom, isn't it?

A. Yes.

Q. Okay. And don't you normally use a chi square to look at something that sort out several outcomes and the chi square gives you an explicit test for how likely it is that these several outcomes came out in this pattern and the real pattern is as specified?

A. Yes.

Q. Okay. There are only two outcomes in this rupture analysis, aren't there? The tube either ruptures or it doesn't; isn't that right?

A. Yes.

Q. Okay. So the poisson distribution takes care of an event happening or nonhappening, doesn't it?

A. Yes, if you define the problem in that fashion.

Q. Okay. Well, that's what we're concerned about here, isn't it?

A. Yes.

Q. Okay.

A. But we're also concerned at this point with -- based on our engineering experience as to what gives us the best bound and the most flexibility with respect to distribution tubes, and therefore the chi square was chosen for this application because we found that in these processes it tends to give us this conservative bound. Now, we have applied poisson and a number of other distributions to these kinds of problems. We find that the chi square tends to be the easiest implement and also bounds. And in fact, for this particular problem we did perform a poisson calculation to find out what were the variations. And the end result was that the chi square was conservative with respect to the data processing.

Q. So is what you're saying that if somebody ran through the poisson calculation on this --

A. We have.

Q. That the chi square would tend to give a higher probability of failure?

A. Yes.

Q. Okay. And that could be checked by somebody running out a poisson distribution, you wouldn't have to do the calculation yourself?

A. Yes.

Q. Now what number of degrees of freedom did you flwspp4

agb/agbl

use on the chi square to get the numbers that you referred to in your answer ten on page six of your testimony?

A. We are simply dealing with that one degree of freedom that you alluded to.

Q. The single degree of freedom. Okay.

And what you are doing is in each of these calculations that are reflected here for the lambda 50 percent and the upper and lower confidence limits at 95 percent, you take a number out of the chi square table and divide it by two times the total number of tube years, is that right?

A. I believe so. I have to refresh my memory on the actual calculations.

Q. You have it in front of you, don't you?

A. I have the results of the calculation.

Q. All right.

Well it says using chi square tables, the confidence value would be this, and it gives an equation, doesn't it?

A. Yes.

Q. That is one degree of freedom, you say?

A. No, it should be two.

Q. At any rate you can check that against the standard table of the chi squared and one or two degrees of freedom, whichever is correct, could you not?

A. Yes. Basically it is all here in doing the calculation.

Q. All right.

As to the matters that you discuss in your answer 13 on page eight, it mentions advances in design of steam generators, operations, maintenance and inspection procedures and so on.

Did you actually review the inspection and operations procedures at Harris in preparing your testimony?

A. I have read through the affidavits that were submitted as to what procedures would be used an an assessment as to whether those procedures were in conformance with standard practices that Westinghouse recommends.

Q. Pardon?

A. I have relied on other expert opinion as to their compliance.

Q. What I was asking you was had you actually examined the procedures themselves?

A. No, not these specific procedures.

Q. Okay.

You describe what you say these advances are in the rest of that answer, do you not?

A. Yes.

agb/agb3

Q At the end of answer 13, on page nine, the second paragraph from the bottom you say:

"Implementation of the modifications to minimize tube vibrations in the Model D-4 steam generators should reduce tube vibration such that they will be at or below the levels contain in the experience base used in the analysis."

What are the tube vibration levels contained in the experience base that you represent in this testimony?

endAGB12
WRB#13flws

A. What page is th. ›xactly?

Q. Page 9, second para.raph from the bottom.

A. The factors I'm referring to is that we have engineering criteria as to what types of work functions are allowed on our tubes due to vibration. There has been a significant amount of research done in this area as to what limitations we want on these work functions to guarantee that the plant will operate for over 40 years without vibration induced degradations.

So there are quantifiable limits that have been set, read over in detail. We've also seen that these modifications have been made to the plant to assure us that these limits are met with margin on this plant. So I have actually reviewed that material.

Q. All right. Now, work function is a measure of the cumulative working of the metal, is that a way to say that?

A. That would be a reasonable characterization.

Q. Okay.

Now, however what you say here is tube vibration levels contained in the experience base. What are those tube vibration levels?

A. The tube vibration levels I'm referring are that we know that all steam generators have tubes that vibrate. It's a fluid situation, you're going to have vibration. We're saying that to guarantee that they said this work function is a criteria that we've imposed on all of our plants to guarantee that the vibrations do not result in an excess of embrittlement or other phenomena that may exist.

From the standpoint of the tube vibration we recognized that in the Model D steam generators there were certain tubes that were more susceptible to vibration that were above this work function. All of those tubes have been identified and modified such that the work function now is below the vibration limits that we set.

Q. Now, when and how did Westinghouse realize that there tubes like that in the Model D steam generator?

A. Based on our inspections on several foreign plants.

Q. Okay. So they actually had them up and running before you found out about this?

A. Yes, they were running -- there was no excessive tube leakage or tube rupture events caused by this kind of phenomena.

Q. But your analysis didn't pick it up before it happened, did it?

A. Two plants went into operation with this kind of a problem, yes.

Q. Okay.

Now, again I'm still not sure that you have answered by original question. What are the tube vibration levels contained in the experience base used in this analysis?

WRB/pp 3

A. What you cannot use is the words vibration. In other words, we're saying that there are vibration levels that you want to minimize. And we're saying that those have been minimized to below level as far as a quantifiable deformation or what's in the data base because, after all, we have not had a flow induced vibration tube rupture event at this point.

So, what I'm saying here is that tube vibration or excess tube vibration had been identified as a potential mechanism for degradation. It never happened. It was identified as an issue.

Q. Are you saying that this tube vibration has never resulted in degradation?

A. Has never resulted in tube rupture.

Q. Okay. It has resulted in degradation, hasn't it?

A. Yes.

Q. Okay. Now, again, and I'm using your words --

A. Well, let me clarify one additional function here, that also in this data base is not only the fact that we detected excess tube vibration but within the data base, once the modifications had been made, we had verified that the vibration levels had been significantly reduced down to within acceptable levels from an engineering standpoint.

Therefore we have monitored and verified that these changes do reduce the probabilities of this kind of degradation process. So we quantified what is the process, what levels are unacceptable. We've made the modifications and also verified and operated plants that the modification does work and will not induce these kinds of problems in the future.

Q. When was that modification first made?

A. I believe it was approximately two years ago.

Q. All right. And you say it was made on two plants that are in your data base?

A. Yes.

Q. So, how many years of operating experience have you got of your modification?

A. Well, essentially, one was in the data base, but from the standpoint of actual operating experience and measurements on the amount of degradation we're seeing, once the modification was made, we've shown that the trends are acceptable at this point, that the degradation is not progressing. After all, these wear rates were very high wear rates to begin with. And we've checked that and the wear rates are exactly as what we're seeing in most of the tubes, either a Model D or other types of steam generators.

Q. So what you're saying is, after you do these modification you get the wear rates on the Model D's down to the same as other steam generators; is that right?

A. Yes.

Q. All right.

WRB/pp 5

A. Well we meet that -- we get the wear rates to within the tolerances of our engineering requirements for design requirements.

Q. Did those tolerances specify a vibration level?

A. Yes.

Q. Okay. And are saying that those vibration levels are met by all the plants within your experience base that you refer to in your appendix?

A. We have looked for this kind of issue in other plants and not found it. So the answer is yes, to the best of my knowledge.

Q. Now, by "this kind of issue" do you mean flow induced vibration leading to a tube rupture?

A. Flow induced vibration that leads to a significant degradation.

Q. Okay.

In your answer 14 on page 10, you explain your judgment of getting that 1.5 number that you used back in your appendix and other places in your testimony, do you not?

A. Yes, I do.

Q. Now, in your table 7, if we may refer to that, you had one failure due to phosphate wastage plus stress corrosion cracking, number one, right?

A. That's correct.

Q. Now, did you, in making your calculation, roughly split that to be half an event caused by phosphate wastage and half an event caused by SCC?

A. No, we did not.

Q. Okay. How did you assign a probability to phosphate wastage to then carry through in your calculations?

A. On the phosphate wastage and the stress corrosion cracking are linked in this section of the analysis. In other words, it's a common phenomenon with the phosphates within the system. The dominant failure mechanism here was the phosphate wastage. Although there was indication of stress corrosion cracking.

Q. All right.

You have two instances there where the attributed cause is a loose part, do you not?

A. Yes, I do.

Q. And you just divided that by two to get your one that you use in your analysis here, didn't you?

A. Yes, I thought that was the margin of improvement.

Q. All right. Now it says on page 9 of your testimony in the middle paragraph discussing this factor of 2, it says,

"Due to rigorous quality assurance procedures as well as monitoring for loose parts, this type of tube leakage event is judged to be much less likely than historical frequency indicates."

Now, what review have you made of the quality

WRB/pp 7

assurance procedures at Harris?

A. Well, there's several things that have been done at this point. I have not reviewed the quality assurance procedures at the plant itself. What I have reviewed where the recommendations have been made and that the plant has agreed to in terms of check list and keeping track of parts that go into and out of the steam generators. Also, the fact that this plant is using loose parts monitors such that when you start up the plant you will be able to hear these things and take corrective actions. So I have not specifically gone through every item in their QA procedure, but I know what the generic recommendations are at this point and those are being adhered to.

Also, I know from the historical record as to what were we seeing at this point. With the number of plants that are currently in operation which we hadn't received -- had another tube rupture of any type much less one that was caused by loose parts since the Ginna incident. So therefore, the trends appear to be showing that we are accumulating data and that we have not seen historical frequencies that we had seen in any of these phenomena.

Q. Well, now, the historical frequency changes every time there's an opinion, doesn't it?

A. That's right.

Q. I mean, for example, a person testifying on October 1,

WRB/pp 8

1979 could have said, according to your table 7,that there had never been a loose part caused occurence of a steam generator tube rupture, couldn't he?

A. He could, but with what confidence. In other words, the response I have here is that it's not only the record that we have that is the reason why you can reduce this but mainly because of the very specific actions that are being implemented at this plant.

Q Okay. So it depends on the implementation of these actions, your result here doesn't it?

A. Yes.

Q. Okay.

Now, you said, "confidence levels." We could calculate, could we not, what the experience base was on October 1, 1979 if we wanted to?

A. Yes, we could.

Q. Okay.

And we could get from that chi squared table the upper bound 95 percent confidence limit on that, couldn't we?

A. Yes.

Q. Okay. And this would all be completely consistent with your methodology as you used it here, wouldn't it?

A. Yes.

Q. If it was done the same way you did it?

A. Yes, you could.

WRB/pp 9

Q. All right.

And let me ask you this: Do you have any calculations available to you or with you as to what the probability and confidence levels are on a loose part caused tube rupture from the Ginna event until the present?

A. I have had sensitivity studies done as to what are the trends that we experience, low types of tests. Those have been done at different times. I don't have them with me.

Q. Okay. Well, now, as to a trend of events, if there aren't events, there's not much of a trend, is there?

A. That's right.

Q. Okay. But it was equally true, say, between October 3, 1979, and January 24, 1982, that there were no events, isn't that true?

A. Yes, but in that case I wouldn't be taking credit for reduction factors as well.

Q. Well, now, are you saying that -- strike that.

In your distributions in your table 8, these are all drawn out of a chi square table also, aren't they, your confidence levels?

A. Yes, they were.

Q. Okay.

Now, the 95 percent confidence level, assuming one and a half failures in your experience base of 3.6 million tube years, is 1.5 in a million, isn't it?

A. That's correct.

Q. And you take that number and run it through the same calculation that you present in page 10 as to failure probabilities, couldn't you?

A. Okay.

Q. Now, let me ask you this: In your summary, I believe you said that a single tube rupture was approximately once in 40 years and not expected to occur in the Harris plant's operating life; did you not?

A. Yes, that's right.

Q. Okay.

Now, when you reduced the number of failures in your experience from 5 to 1.5, that's a reduction by a factor of 3.3, approximately, isn't it?

A. Approximately.

Q. Okay.

And you could check that figure by a single calculation, couldn't you?

A. Oh, yes.

Q. Okay.

Now, if you reduce one in 40 years by a factor of 3.3, you would come out with one in a 130 years, wouldn't you?

A. I assume so.

Q. Well, you can check that again by calculations, couldn't you?

WRB/pp 11

A. Yes.

Q. Okay.

To the extent that the average failure rates were different than what you have calculated here, the probability of failure of tube ruptures, multiple tube ruptures, would be either higher or lower than you calculated; isn't that true?

A. Yes.

Q. Now, when you calculated your single tube rupture frequency -- I'm at the bottom of answer 17 on page 11, would you refer to that please?

There is a calculated single tube rupture of 7.5 times ten to the minus three per year. Now, that's from Exhibit A, or Attachment A; is it not?

A. Yes.

Q. I think you call it Exhibit A but it's called Attachment A when you actually get to it; is that correct?

A. I think so.

End 13

14 fls

Q I have to confess that I can't find the 7-1/2 times.... Oh, there it is.

On the number of tubes rupturing on page 26, it has got a probability of 7.5 times 10 to the minus 3. Correct?

A Yes.

Q Now that was calculated by this weighting procedure off the binomial distribution. Correct?

A That's right.

Q Okay.

Would you say it is likely that the difference of those two probabilities takes into some account the possibility of multiple failures, the difference between the 7.5 and the 8.2 times 10 to the minus 3?

A I'm not certain how I make that link. Could you give me a little more detail?

Q Okay.

Let's suppose that we had an idea sort of world where we really knew what the probability of a failure is. We know that the probability of the number of total failures let's say was 8.2 times 10 to the minus 3. And if in that situation multiple failures were possible, then if you had a perfect table again telling you what the probabilities of one failing at a time, two failing at a time, three failing at a time and so on were, you could do the same kind of summation technique that we went through with the Poisson distribution, could we not?

In other words, if you take the probability of one tube failing times one, plus the probability of two tubes failing times two, plus the probability of three tubes failing times three, plus the probability of N tubes failing times N for every N, add that all up, and that would come out to be your 8.2, wouldn't it?

A Yes.

Q Okay.

So in that case the difference between the probability of a single rupture by itself and the probability of tube rupture, period, number of ruptures per number of tube years, that difference would in that case reflect the multiple tube ruptures, wouldn't it?

A It would in the example you gave, yes.

Q All right.

JUDGE KELLEY: Are we close to a break point?

MR. EDDLEMAN: Yes.

JUDGE KELLEY: Now?

MR. EDDLEMAN: Fine.

JUDGE KELLEY: Ten minutes.

xzxxxzx (Recess.)

JUDGE KELLEY: We're back on the record.

The Board was talking with the parties also about the prospect of possibly making the record a little easier to read. We are aware of the fact that the excerpt from "Probability and Statistics," this chapter on the "Poisson Distribution," was used as a basis for cross. It is not being offered as evidence itself, but since it is difficult material, we thought it might be useful in reading the transcript just to fold that in like we do testimony, with the understanding that it is not evidence but just to clarify the material.

Is there any problem with that?

MR. O'NEILL: No, sir.

MR. EDDLEMAN: No objection.

JUDGE KELLEY: Why don't we do that and then, in addition, the Reporters as they type this material-- The equations particularly I think may be difficult for them, and they may be checking with the witness or the parties about particular parts of it, so that we can get it all straight.

(The document follows:)

Books by Allen L. Edwards

Experimental Design in Psychological Research, Third Edition
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Chapter 11

The Poisson Distribution

11.1 Introduction

Assume we have a box containing N marbles of which m are red, so that if we select a marble at random we have $P(R) = m/N$. We draw a random sample of $n = N$ with replacement after each draw. We let T be the number of red marbles and T can take the possible values of 0, 1, 2, ..., N. Because we are sampling with replacement, the drawings are independent. We now consider the probability distribution of T as N, the number of marbles in the box, becomes indefinitely large, while m, the number of red marbles in the box, remains fixed. We consider first a simple example.

11.2 An Example of a Poisson Distribution

Suppose that $m = 5$ and $N = 100$ so that $P = 0.05$. Then, if we draw a random sample of $n = N$ with replacement after each draw, we have

$$\mu_T = NP = (100)(0.05) = 5$$

and

$$\sigma_T^2 = NPQ = (100)(0.05)(0.95) = 4.75$$

and we note that σ_T^2 is close to the value of μ_T.

Now, suppose that we increase the number of marbles to $N = 1000$, leaving m, the number of red marbles, fixed at $m = 5$. In this case, we have $P = \frac{5}{1000} = 0.005$. We now draw a random sample of $n = N = 1000$ with replacement after each draw. Then

$$\mu_T = NP = (1000)(0.005) = 5$$

and

$$\sigma_T^2 = NPQ = (1000)(0.005)(0.995) = 4.975$$

and we note that σ_T^2 is even closer in value to μ_T than when we had $n = N = 100$, with $m = 5$.

With $N = 10{,}000$ marbles and $m = 5$ red marbles, we have $P = 0.0005$. If we draw a random sample of $n = N = 10{,}000$ with replacement after each draw, then

$$\mu_T = NP = (10{,}000)(0.0005) = 5$$

and

$$\sigma_T^2 = NPQ = (10{,}000)(0.0005)(0.9995) = 4.9975$$

It seems obvious, from this example, with m fixed, as N becomes indefinitely large so that P becomes small, then σ_T^2 approaches μ_T. This is characteristic of the *Poisson* distribution for which the probabilities of the sum T are given by[1]

$$P(T = r) = \frac{m^r e^{-m}}{r!} \qquad (11.1)$$

where r can take values of 0, 1, 2, ... We now consider a proof of (11.1).

11.3 The Limiting Value of $\left(1 - \frac{m}{N}\right)^N$ and $\left(1 + \frac{m}{N}\right)^N$ as N Becomes Indefinitely Large

If we expand $(a - b)^N$ with N indefinitely large, then we have the series

$$a^N - Na^{N-1}b + \frac{N(N-1)}{2!}a^{N-2}b^2 - \frac{N(N-1)(N-2)}{3!}a^{N-3}b^3 + \cdots$$

We let $a = 1$ and $b = m/N$ with N indefinitely large. Then

$$a^N = a^{N-1} = a^{N-2} = \cdots = 1$$

and in this case we have $(a - b)^N$ equal to

$$\left(1 - \frac{m}{N}\right)^N = 1 - m + \frac{N(N-1)}{2!N^2}m^2 - \frac{N(N-1)(N-2)}{3!N^3}m^3 + \cdots$$

[1] The symbol e represents the number 2.7183.... It appears frequently in mathematics and is the base of the system of natural logarithms.

It may be noted that the third term on the right side of the equation can be written as

$$\left(\frac{N}{N}\right)\left(\frac{N-1}{N}\right)\left(\frac{m^2}{2!}\right) = 1\left(1-\frac{1}{N}\right)\frac{m^2}{2!}$$

and as N becomes large, $1/N$ approaches zero and this term approaches $m^2/2!$. Similarly, the fourth term can be written as

$$-\left(\frac{N}{N}\right)\left(\frac{N-1}{N}\right)\left(\frac{N-2}{N}\right)\left(\frac{m^3}{3!}\right) = -1\left(1-\frac{1}{N}\right)\left(1-\frac{2}{N}\right)\left(\frac{m^3}{3!}\right)$$

and as N becomes large the fourth term approaches $-m^3/3!$. Thus, with N indefinitely large, we have

$$\left(1-\frac{m}{N}\right)^N = 1 - m + \frac{m^2}{2!} - \frac{m^3}{3!} + \frac{m^4}{4!} - \frac{m^5}{5!} + \cdots$$

and this series is one way of writing e^{-m}. Thus

$$\left(1-\frac{m}{N}\right)^N = e^{-m} \tag{11.2}$$

as N becomes indefinitely large.

In the same manner, it can be shown that as N becomes indefinitely large, then

$$\left(1+\frac{m}{N}\right)^N = 1 + m + \frac{m^2}{2!} + \frac{m^3}{3!} + \frac{m^4}{4!} + \frac{m^5}{5!} + \cdots$$

and this series is one way of writing e^m. Thus

$$\left(1+\frac{m}{N}\right)^N = e^m \tag{11.3}$$

as N becomes indefinitely large.

11.4 The Probability Distribution of T as N Grows with m Fixed

Consider again the problem of the box of marbles with $m = 5$ red marbles remaining fixed while the number of marbles in the box becomes indefinitely large. We draw a random sample of $n = N$ marbles with replacement after each draw. As N grows, with m fixed, then $P = m/N$ becomes small and

$$P(T = 0) = Q^N = \left(1-\frac{m}{N}\right)^N$$

will tend to e^{-m}.

To determine the probability that $T = 1$, we have

$$P(T = 1) = NPQ^{N-1}$$

and we note that

$$Q^{N-1} = \left(1-\frac{m}{N}\right)^N\left(1-\frac{m}{N}\right)^{-1}$$

Then

$$P(T = 1) = NPQ^{N-1} = N\frac{m}{N}\left(1-\frac{m}{N}\right)^N\left(1-\frac{m}{N}\right)^{-1}$$

If N is large relative to m, then

$$\left(1-\frac{m}{N}\right)^N \quad \text{and} \quad \left(1-\frac{m}{N}\right)^{-1}$$

will tend to e^{-m} and 1, respectively. Then, $P(T = 1)$ will be approximately

$$P(T = 1) = me^{-m}$$

In the same manner, we see that

$$P(T = 2) = \frac{N(N-1)}{2!}P^2Q^{N-2}$$

$$= \frac{N(N-1)}{2!}\left(\frac{m}{N}\right)^2\left(1-\frac{m}{N}\right)^N\left(1-\frac{m}{N}\right)^{-2}$$

and $P(T = 2)$ will be approximately equal to

$$P(T = 2) = \frac{m^2e^{-m}}{2!}$$

or, in general, $P(T = r)$ will be approximately given by

$$P(T = r) = \frac{m^re^{-m}}{r!} \tag{11.4}$$

Letting r take values of 0, 1, 2, 3, . . . , we see that the sum of the probabilities defined by (11.4) will be

$$\sum_{r=0}^{\infty}\frac{m^re^{-m}}{r!} = e^{-m} + me^{-m} + \frac{m^2e^{-m}}{2!} + \frac{m^3e^{-m}}{3!} + \cdots + \frac{m^re^{-m}}{r!} + \cdots$$

$$= e^{-m}\left(1 + m + \frac{m^2}{2!} + \frac{m^3}{3!} + \cdots + \frac{m^r}{r!} + \cdots\right)$$

and the series within the parentheses is e^m. Thus, we have

$$\sum_{r=0}^{\infty}\frac{m^re^{-m}}{r!} = e^{-m}e^m = 1 \tag{11.5}$$

11.5 The Expected Value of T for the Poisson Distribution

By definition, $\mu_T = \Sigma P_iT_i$. According to (11.4) we have

$$P(T = r) = m^re^{-m}/r!$$

where r can take the values of 0, 1, 2, 3, ... Then

$$\mu_T = \sum_{r=0}^{\infty} \frac{m^r e^{-m}}{r!} r$$

or

$$\mu_T = e^{-m}(0) + me^{-m}(1) + \frac{m^2e^{-m}}{2!}(2) + \frac{m^3e^{-m}}{3!}(3) + \frac{m^4e^{-m}}{4!}(4) + \cdots$$
$$= me^{-m}\left(1 + m + \frac{m^2}{2!} + \frac{m^3}{3!} + \cdots\right)$$

The limit of the sum within the parentheses is e^m and therefore

$$\mu_T = \sum_{r=0}^{\infty} \frac{m^r e^{-m}}{r!} r = me^{-m}e^m = m \tag{11.6}$$

11.6 The Variance of T for the Poisson Distribution

To find the variance of T, we first find $E(T^2) = \Sigma P_iT_i^2$, where the values of P are given by (11.4) and the values $T = r$ are 0, 1, 2, 3, ... In other words, we want to find

$$\sum_{r=0}^{\infty} \frac{m^r e^{-m}}{r!} r^2 = \Sigma P_iT_i^2$$

or

$$\Sigma P_iT_i^2 = e^{-m}(0)^2 + me^{-m}(1)^2 + \frac{m^2e^{-m}}{2!}(2)^2 + \frac{m^3e^{-m}}{3!}(3)^2 + \frac{m^4e^{-m}}{4!}(4)^2 + \cdots$$
$$= m\left(e^{-m}(1) + me^{-m}(2) + \frac{m^2e^{-m}}{2!}(3) + \frac{m^3e^{-m}}{3!}(4) + \cdots\right)$$

Note that the general term within the parentheses is of the form

$$\frac{m^r e^{-m}}{r!}(r+1)$$

and that for the successive terms we have $r = 0, 1, 2, 3, \ldots$. Then

$$\Sigma P_iT_i^2 = m\left[\sum_{r=0}^{\infty} \frac{m^r e^{-m}}{r!}(r+1)\right]$$
$$= m\left[\sum_{r=0}^{\infty} \frac{m^r e^{-m}}{r!} r + \sum_{r=0}^{\infty} \frac{m^r e^{-m}}{r!}\right]$$

But, according to (11.6), the first sum in the above equation is equal to

m and the second sum, according to (11.5), is equal to one. Therefore

$$\Sigma P_iT_i^2 = m(m+1)$$

Then for the variance of T, we have

$$\sigma_T^2 = \Sigma P_iT_i^2 - \mu^2$$
$$= m(m+1) - m^2$$
$$= m \tag{11.7}$$

11.7 The Binomial Distribution: $(P + Q)^N$

If $P = m/N$, then the exact probabilities associated with the possible values of T will be given by

$$(P+Q)^N = \left(\frac{m}{N} + \frac{N-m}{N}\right)^N = \left[\frac{m}{N} + \left(1 - \frac{m}{N}\right)\right]^N$$

The probabilities given by (11.4) are approximations of the above probabilities when m is fixed and as N becomes indefinitely large.

For the binomial distribution, with $n = N$,

$$\mu_T = NP = N\frac{m}{N} = m$$

and for the variance of T, we have

$$\sigma_T^2 = NPQ = N\frac{m}{N}\left(1 - \frac{m}{N}\right)$$

If N is large relative to m, then $(1 - m/N)$ is approximately one and in this case σ_T^2 will be approximately equal to m.

In Table 11.1, we give the probabilities for values of T from 0 through 15 obtained from the binomial distribution with $m = 5$ and $N = 1000$. The table also gives the probabilities of T as obtained from (11.4). All of the probabilities have been rounded to four decimal places. We note that, in general, the correspondence between the two sets of probabilities is very good.

11.8 Another Distribution in which $\mu_T = \sigma_T^2$

For the Poisson distribution, we have $\mu_T = \sigma_T^2$ as N becomes indefinitely large with m fixed, so that $P = m/N$ becomes small. We now consider another distribution of T in which $\mu_T = \sigma_T^2$ for any value of $N \geq 2$. This distribution of T arises from a problem called the *matching* problem.

Suppose we have a deck of N distinct experimental cards which are

Table 11.1 The Probability Distribution of the Sum T for Random Samples of $n = 1000$ Drawn from a Binomial Population in which $P(X = 1) = 0.005$ and the Poisson Distribution Approximation of the Probabilities of T

T	Binomial	Poisson
0	0.0066	0.0067
1	0.0332	0.0337
2	0.0833	0.0842
3	0.1393	0.1404
4	0.1745	0.1755
5	0.1746	0.1755
6	0.1456	0.1462
7	0.1039	0.1044
8	0.0648	0.0653
9	0.0359	0.0363
10	0.0179	0.0181
11	0.0081	0.0082
12	0.0033	0.0034
13	0.0013	0.0013
14	0.0005	0.0005
15	0.0001	0.0002

placed face down in a random order. A second identical, or matching, deck is thoroughly shuffled and each card is placed face down in order under the first deck. We now turn the cards over and count the number of times that the card in the matching deck is identical to the corresponding card in the experimental deck.

The matching deck can be arranged in $N!$ orders and we assume that each order has a probability of $1/N!$. We are interested in T, the number of matches, that is, the number of times that the card in the matching deck is the same as the paired card in the experimental deck. In particular, we are interested in μ_T and σ_T^2. We consider first a simple example.

11.9 An Example of the Matching Distribution

We have an experimental deck consisting of $N = 3$ cards, the ace, king, and queen of hearts. These cards are placed face down in a random order. Then the matching deck consisting of the same $N = 3$ cards is shuffled

and the cards are placed face down under the cards in the experimental deck.

The cards in the matching deck can be arranged in $N! = 3! = 6$ possible orders and we assume that each order is equally likely with a probability of $\frac{1}{6}$. The six orders in which the matching deck may be arranged are: AKQ, AQK, KAQ, KQA, QKA, and QAK. The cards in the experimental deck must also be in one of the six possible orders, and the particular order of these cards does not affect the expected number of matches. Assume that the experimental deck is in the order AKQ. The six possible orders of the matching deck will then result in the number of matches shown below:

AKQ	Number of Matches
AKQ	3
AQK	1
KAQ	1
KQA	0
QKA	1
QAK	0

and each of the above outcomes has a probability of $\frac{1}{6}$. It can easily be verified that any other order of the experimental deck than AKQ will yield the same distribution of matches.

The probability distribution of T is given in Table 11.2, and we note that $E(T) = \Sigma P_iT_i = \mu_T = 1$. We also have $\sigma_T^2 = \Sigma P_i(T_i - \mu_T)^2 = 1$. In the present example with $N = 3$, we have both μ_T and σ_T^2 equal to one. We now show that $\mu_T = 1$ and $\sigma_T^2 = 1$, for any value of $N \geq 2$.

Table 11.2 The Probability Distribution of T, the Number of Correct Matches

T_i	P_i	P_iT_i	$(T_i - \mu_T)^2$	$P_i(T_i - \mu_T)^2$
3	$\frac{1}{6}$	$\frac{3}{6}$	4	$\frac{4}{6}$
1	$\frac{3}{6}$	$\frac{3}{6}$	0	0
0	$\frac{2}{6}$	0	1	$\frac{2}{6}$
Σ	1	1		1

11.10 The Expected Value of T for the Matching Distribution

Consider a random variable X that takes a value of 1 when a match is made and 0 otherwise. We have previously shown that for a variable of this kind

$$\mu = P \quad \text{and} \quad \sigma^2 = PQ$$

where P is the probability that $X = 1$ and $Q = 1 - P$ is the probability that $X = 0$. Then T, the number of correct matches, is a sum of N such variables or

$$T = X_1 + X_2 + \cdots + X_N$$

where $X_1, X_2, \ldots, X_N$ is the ordered sequence of the cards in the matching deck.

Each card has a probability of $1/N$ of occupying any one of the N possible positions in the ordered sequence. Thus the probability that a card is a match, or that $X = 1$, is equal to $1/N$ for each of the N cards. Then

$$E(X_1) = E(X_2) = \cdots = E(X_N) = \frac{1}{N}$$

and

$$E(T) = N\left(\frac{1}{N}\right) = 1 \tag{11.8}$$

11.11 The Variance of T for the Matching Distribution

To find the variance of T, we first consider the variance for any one of the ordered values of X. We have $P(X = 1) = 1/N$ and $Q = 1 - P$ as the probability that X is 0. Then

$$\sigma^2 = PQ = \frac{1}{N}\left(1 - \frac{1}{N}\right) = \frac{N-1}{N^2} \tag{11.9}$$

If $X_1, X_2, \ldots, X_N$ were independent random variables, then the variance of T would simply be $N\sigma^2$. However, the variance of T involves covariance terms of the form

$$C_{ij} = E(X_i - \mu)(X_j - \mu) = E(X_iX_j) - \mu^2$$

or, because $\mu = P = 1/N$,

$$C_{ij} = E(X_iX_j) - \frac{1}{N^2}$$

To find $E(X_iX_j)$, we note that the product X_iX_j is 0 or 1 and that it can be 1 only if the ith and jth cards are both matches. Given that the ith card is a match, the probability that the jth card is a match will be $1/(N - 1)$ so that P_{ij}, the probability that both cards are matches, will be

$$P_{ij} = P(X_i = 1 \text{ and } X_j = 1) = \frac{1}{N}\left(\frac{1}{N-1}\right) = \frac{1}{N(N-1)}$$

Then

$$E(X_iX_j) - \mu^2 = \frac{1}{N(N-1)} - \frac{1}{N^2} = \frac{1}{N^2(N-1)}$$

The variance of the sum T will then be given by

$$\sigma_T^2 = N\sigma^2 + N(N-1)C_{ij} \tag{11.10}$$

or

$$\sigma_T^2 = \frac{N(N-1)}{N^2} + \frac{N(N-1)}{N^2(N-1)} = \frac{N}{N} = 1 \tag{11.11}$$

It is interesting to note that no matter how large N is, that is, for all values of $N \geq 2$, the expected number of correct matches is always one and the variance of the number of correct matches is also one.

11.12 The Matching Distribution and the Poisson Distribution

As N becomes indefinitely large, the covariance term in (11.10),

$$N(N-1)C_{ij} = \frac{N(N-1)}{N^2(N-1)} = \frac{1}{N}$$

will approach zero and the variance of T will be approximately equal to $N\sigma^2$ or

$$\sigma_T^2 = NPQ$$

Then, in this case, the binomial distribution

$$(P + Q)^N = \left[\frac{1}{N} + \left(1 - \frac{1}{N}\right)\right]^N$$

should give the approximate probability distribution of T.

We note that if

$$\sigma_T^2 = NPQ = N\frac{1}{N}\left(1 - \frac{1}{N}\right) = 1 - \frac{1}{N}$$

then, as N becomes indefinitely large, $1/N$ will approach zero and the variance of T will be approximately one.

Furthermore, by the methods used earlier in the chapter, it can be shown that as N becomes indefinitely large, then

$$\left(1 - \frac{1}{N}\right)^N = 1 - N\left(\frac{1}{N}\right) + \frac{N(N-1)}{2!N^2} - \frac{N(N-1)(N-2)}{3!N^3} + \cdots$$

$$= 1 - 1 + \frac{1}{2!} - \frac{1}{3!} + \frac{1}{4!} - \frac{1}{5!} + \cdots$$

and this series is one way of writing e^{-1}. Similarly, as N becomes indefinitely large,

$$\left(1 + \frac{1}{N}\right)^N = 1 + 1 + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \frac{1}{5!} + \cdots$$

and this series is one way of writing e.

Note that the only difference between the last two series and those developed previously is that instead of $P = m/N$, we have $P = 1/N$ or, in other words, $m = 1$. Substituting 1 for m in (11.4), we obtain

$$P(T = r) = \frac{e^{-1}}{r!} \qquad \textbf{(11.12)}$$

Thus, with N indefinitely large, the probabilities given by (11.12) should be a good approximation of those associated with the various possible values of T.

PROBLEMS

11.1 An experimental deck consisting of four different cards is placed face down in random order. A matching deck of the same four cards is placed face down in random order under the cards in the experimental deck. Let T be the number of cards that are matched in the two decks. (a) Find the probability distribution of T. (b) Use the probability distribution of T to calculate μ_T and σ_T^2.

11.2 From a deck of playing cards select the ace, king, queen, and jack of one suit to be the experimental deck. Place these cards face up in any order. Select the ace, king, queen, and jack of another suit for the matching deck. Shuffle the matching deck thoroughly and then place the cards in the matching deck under those in the experimental deck and count the number of matches. Repeat the experiment 100 times. Is the observed distribution of T, the number of matches, reasonably in accord with the theoretical distribution obtained in Problem 11.1?

11.3 If in the matching problem $N = 2$, what are the possible values of T and what are the probabilities of the values? It is easy, in this instance, to show that both μ_T and σ_T^2 are equal to one.

11.4 Prove that the sum of the probabilities defined by (11.12) is one. In other words, prove that

$$\sum_{r=0}^{\infty} \frac{e^{-1}}{r!} = 1$$

11.5 Prove that if $T = r$ can take values of 0, 1, 2, 3, . . ., with probabilities defined by (11.12), then

$$\mu_T = \sum_{r=0}^{\infty} \frac{e^{-1}}{r!} r = 1$$

11.6 Prove that if $T = r$ can take values of 0, 1, 2, 3, . . ., with probabilities defined by (11.12), then

$$\Sigma P_i T_i^2 = \sum_{r=0}^{\infty} \frac{e^{-1}}{r!} r^2 = 2$$

11.7 We have a random variable X that can take values of 0 or 1 with corresponding probabilities of 0.9 and 0.1. Let T be the number of values of $X = 1$ in a random sample of $n = 10$. (a) Find the probability that $T = 2$ using the binomial distribution. (b) Find the probability that $T = 2$ using the Poisson approximation to the binomial distribution.

11.8 We have a variable X that can take values of 0 or 1 with corresponding probabilities of 0.99 and 0.01. Let T be the number of values of $X = 1$ in a random sample of $n = 100$. Use the Poisson approximation to the binomial distribution to find the following probabilities: (a) $P(T = 0)$, (b) $P(T = 1)$, (c) $P(T = 2)$, (d) $P(T = 3)$.

11.9 Calculate to four decimal places the first eight terms of

$$1 + 1 + \frac{1}{2!} + \frac{1}{3!} + \frac{1}{4!} + \cdots$$

How well does the sum of the eight terms approximate $e = 2.7183\ldots$?

11.10 Calculate to four decimal places the first eight terms of

$$1 - 1 + \frac{1}{2!} - \frac{1}{3!} + \frac{1}{4!} - \frac{1}{5!} + \cdots$$

How well does the sum of the eight terms approximate e^{-1}?

11.11 Calculate to four decimal places the first eight terms of

$$1 + m + \frac{m^2}{2!} + \frac{m^3}{3!} + \frac{m^4}{4!} + \frac{m^5}{5!} + \cdots$$

with $m = 2$. How well does the sum of the eight terms approximate e^m?

11.12 Calculate to four decimal places the first eight terms of

$$1 - m + \frac{m^2}{2!} - \frac{m^3}{3!} + \frac{m^4}{4!} - \frac{m^5}{5!} + \cdots$$

with $m = 2$. How well does the sum of the eight terms approximate e^{-m}?

JUDGE KELLEY: Okay.

THE WITNESS: May I make a clarification, please?

JUDGE KELLEY: Yes.

THE WITNESS: One of the questions that was asked was the number of degrees of freedom in the chi-square calculation, so in the interest of being able to reproduce the calculation, I said I was uncertain as to what the exact number was. The exact number in checking was 12 degrees of freedom that should be used.

JUDGE KELLEY: Thank you.

BY MR. EDDLEMAN:

Q Now let me-- I am tempted to ask what the probability is that you will have another correction if we have another break, but I won't.

On page 24, in your Equation 1 there, you've got a P equals .029 lambda T per tube.

Does that assume that each tube's failure or rupture will be an independent event?

A Yes.

Q Okay.

Now back over here on page 26-- I'm sorry, that is probably not the chi-square that has 12 degrees of freedom, or is it?

Do you see where I'm talking about, up at the top of page 26 where you refer to the chi-square that you got the lower tail on that distribution from?

A Yes.

Q Was that the one with 12 degrees of freedom, or is it the one that you used to get the 95 percent confidence limits in your -- I think it is Table 8, and otherwise in your testimony?

A It is the one that I used to derive the 95 percent confidences in the early part of the testimony. It is also used in the derivation of the 10 percent number.

In other words, at the bottom of the table where we have the number of 1.6 times 10 to the minus 7, it is used in that calculation also.

Q Did you use it in calculating the number of 1.6 times 10 to the minus 7?

A That's right.

Q How was it used to do that?

A I was assuming that we have the 6 times 10 to the minus 6 as our data point. You then use the basic tables to come down to what is the fifth percentile value with the 12 degrees of freedom.

Q And that's the 1.6 times 10 to the minus 7?

A Yes.

Q All right.

Now just what are these 12 degrees of freedom that we're dealing with here? What are the 12 things that can vary?

A Well, in applying it to the basic equation that you're using, the basic formula is to take the number of events which is five, multiple that by two and add two, and what that essentially does it tell you or it gives you a reference point for the number of events that have actually occurred to date.

Q Well, now, knowing that, how could you possibly have said it was one or two degrees of freedom before?

A I was just confused at that point.

Q Are you sure that this is right this time?

A I'm positive. It is just that I drew a mental blank at that point.

Q All right.

So again if you used the 12 degrees of freedom, which we now agree is how you did it, that would be a standard procedure and you could check against the standard text of statistics and you could use the standard table of the chi-squared distribution to get the same numbers that you got in your testimony. Right?

A Yes.

Q Okay.

Turn to page 12 of your testimony, please.

You start talking about results of PRA analyses sort of in the middle of Answer 19, the second paragraph of Answer 19.

Has there been a complete PRA on the Harris plant?

A No, there has not.

Q Did you perform the PRA on the steam generators yourself, or was it done under your direction?

A Under my direction,in some parts, directly myself.

Q Okay.

And so when we have this passive voice frequency was estimated to be, what you are saying is you and your people estimated that frequency. Correct?

A That's right.

Q Now do you show anywhere in your testimony or appendices how you calculated that number?

A No, we do not.

Q Do you show any of the assumptions you made in order to get that number?

A No, we do not.

Q Okay.

When you have the 3 percent of the frequency there, the one times 10 to the minus 8 as compared to 10 times 3 to the minus 7, is the difference there due to assumptions or is it due to the analysis of frequency of the multiple ruptures?

A It is due to both.

Q Okay.

So you cannot just take the multiple rupture frequency and multiply by the number of ruptures and apply that to 3 times 10 to the minus 7 and get the 10 to the minus 8, can you?

A Definitely not.

Q Okay.

If you have several ruptures-- Well, let me say if you have two or more ruptures at the same time in the steam tubes, the total loss of the primary coolant through those ruptures will be basically the sum of the flows through each rupture. Right?

A At any given point in time until -- well, very early in the transient, yes.

Q Okay.

A Not later on.

Q All right.

But when you first started to lose coolant that way, several of them happened, or if one happened and then another one happened soon thereafter, it would be in the terms I've described? Right?

A No, not really, because in looking at the way a two-rupture event occurs, you find you have some natural limitations as to the leak rates.

One of the most important limitations is in terms of the amount of high-head safety injection flow you have. Once you get out beyond a certain number of tube ruptures, you essentially see no change in the overall transient progression.

Q In other words what you're saying is if the leaks are taking coolant out as fast as they can be injected then more leaks aren't going to make any di: ˉ rence because everything that is being injected comes out?

A Yes, essentially you are stabilizing at a certain point.

Q Well, wouldn't it be possible under those conditions for the core itself to begin to overheat due to a lack of coolant and blowing more coolant out through those ruptures?

A No, because what happens is not in that fashion. You do not have a essentially a mechanism for what I will call vacuuming out the primary fluid, that you reach an equilibrium state in which the faulted steam generator starts to act just like a pressurizer.

In other words, you've just expanded-- You have added another void in the reactor coolant system. You have the pressurizer normally. With a tube rupture what you have essentially done is started having a second pressurizer develop and you stabilize the plant based on this new pressure boundary. You have a link between the primary and the secondary system.

Q Does that answer assume that all the ruptures happen in the same steam generator?

A Specifically yes, but you can extrapolate that to the other answers or to the other steam generators as well. You can throttle the other steam generators even if they have a tube rupture and in fact the procedures that have been developed for Harris and all Westinghouse plants at this point take that possibility into account and request that -- and warn the operator that he may have that occur and that he must just throttle the steam releases and maintain the pressure differential.

Q Now by throttling steam releases you are talking about releasing steam off the secondary side?

A Yes.

Q Where would that be released?

A Through the relief valves or safety valves.

Q Inside containment or to the atmosphere?

A To the atmosphere until you were able to cool the primary system down through the RHR system, the residual heat removal system.

Q So if you got one of these events you could be releasing steam to the atmosphere until you got it under control, assuming your analysis is correct?

A That is one of the very rare events that you must consider.

Q In your Answer 20 did you or your people working under you play any role in putting together NUREG 0844?

A We did not put together the documents. There were various drafts that we were asked to comment on.

Q So your comments may have been incorporated in it but you were not authors or assemblers of the document?

A No, we were not.

Q All right.

And it is true, isn't it, that you haven't done an FSAR type of analysis of a multiple tube rupture for a Westinghouse plant?

A We have done-- Myself, personally, no.

Westinghouse and the people within my department have done those calculations in the generation of emergency response guidelines that are implemented at the plant.

Q Well, if those calculations had been done, is that consistent with your testimony of saying it is just not worth doing them?

A The intent of the iterating procedures is to provide an all-encompassing protection mechanism for the plant, irrespective of what may cause the accident. We were requested to do those kind of calculations to show that we would not get into an impossible recovery condition from multiple tube ruptures.

Now the request was made in terms of probabilistic calculations that were done post-TMI in which a large series of scenarios were postulated and sorted upon to find out which we should have emergency procedures written for.

The criteria that was used at that point was a very conservative criteria and so some best-estimate calculations were done for those events.

Q When were those calculations done, do you know?

A Well, they have been on-going. They started, to the best of my recollection, in approximately 1980 or 1981, and they have been continuing as we have been developing the emergency response guidelines used at Harris. The most recent revision occurred I believe last December.

Q And are those the same as the PRA that you referred to in your testimony?

A The PRA that I referred to in the testimony takes advantage of the procedures that are being implemented at Harris and other plants.

The actual probabilistic assessment that was used is much more detailed than the original scoping study done for the procedures.

Q Let me ask you this:

Is that PRA that you are talking about here a proprietary document?

A No, it is not.

Q Does it have a WCAP number or something like that?

A Yes, it does.

Q Do you know what the number is?

A Well, the basis for the calculation comes from the Italian referenced design analysis that I alluded to in the front of my testimony. That was used because that was a three-loop plant design and did use the same set of emergency response guidelines.

End 14

#15, WRBwbl

Q The Italian plant has the same emergency response guidelines?

A Yes, they do.

MR. EDDLEMAN: No more questions.

JUDGE KELLEY: Thank you.

The Staff?

MS. MOORE: Your Honor, may I have a moment, please?

JUDGE KELLEY: Surely.

(Pause.)

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CROSS-EXAMINATION

BY MS. MOORE:

Q Mr. Hitchler, I just have a few questions.

Will you turn in your testimony to Table 7?

A Yes.

Q In that testimony you have a leak rate for Surry of 80 gpm; is that correct?

A That's right.

Q Could you tell me where that leak rate was obtained?

A Those were Westinghouse calculations as to what types of losses occur. I could provide you with the exact details of how the number was calculated.

Q Could you tell me, then, what your reference to NUREG-0651 relates to in Table 7?

WRBwb2

A. Well, a number of these flow rates were taken from that document.

Q. But you did not take the Surry rate from that document?

A. I believe they are about the same.

Q. Do you have a copy of NUREG-0651, by any chance?

A. I don't think so.

MS. MOORE: Your Honor, I would like to show the witness that NUREG, if that is accep ble.

JUDGE KELLEY: Sure, go ahead.

MS. MOORE: If counsel wishes to see it, that's fine.

(Document handed to the witness.)

MR. O'NEILL: Mr. Chairman, I would like to ask for an in-place break. We have some information we just got that may help the witness answer this question.

JUDGE KELLEY: Okay.

MR. O'NEILL: Just for about two minutes.

JUDGE KELLEY: All right.

(Whereupon a brief recess was taken.)

MR. O'NEILL: Thank you.

JUDGE KELLEY: Does the new information pertain to one of Mr. Eddleman's questions or to one of the Staff's questions, or how does it fit into the general scheme of things?

WRBwb3

MR. O'NEILL: To the Staff's question.

JUDGE KELLEY: All right. Thank you.

THE WITNESS: Let me explain what those numbers mean in terms of the leak rates that are shown in this table, because that's where really the difference in the flow rates that we are talking about exists.

MS. MOORE: Your Honor, it's not that I want to interrupt the witness, but I think the record is not going to be quite clear what's happening.

JUDGE KELLEY: Are we backtracking to an earlier question?

MS. MOORE: No. What just happened is, I have just shown Mr. Hitchler NUREG-0651 and I was going to direct his attention to Table 10 of that document, and then I would like to ask him a question, just because I think the record would be clearer if we did it that way.

JUDGE KELLEY: Okay.

MS. MOORE: And then he can explain his answer to it.

JUDGE KELLEY: All right.

BY MS. MOORE:

Q Mr. Hitchler, on Table 10 could you tell us what the leak rate for Surry on that table is?

A 330 gpm actual.

Q And what is the leak rate for Surry given in your

WRBwb4

testimony at Table 7?

A. 80 gpm.

Q. Could you explain to me the difference between the leak rate that you have given and the leak rate in Table 10?

A. Okay. The 80 gpm that is referenced in Table 7 refers to what was the leak rate when the tube rupture occurred. In other words, the isntantaneous rate when the plant -- when the rupture occurred.

Now, after the rupture occurred, in the longer term time frame, you can get higher leak rates because you are re-pressurizing the system up to potentially high pressures once you have actuated safety injection, so you can get somewhat higher leak rates.

The information, or the difference also is due to where this data came from in terms of what's in the NUREG versus what we used in the table. The source of the 330 gpm in the NUREG came from strip charts at the plant, of which there is some serious doubt as to the accuracy of those strip charts.

So it is true that the 330 gpm was a piece of data that was available from the plant. The operating staff, however, did not express a high degree of confidence as to the accuracy of this.

So, therefore, we went back and estimated what was that expected leak rate instantaneously for the size tubes. In fact, they even mentioned earlier that the tubes at Surry were pulled by Westinghouse to analyze the actual breaks and tears to see what size we were dealing with. That was part of that evaluation.

Q. Does the difference in these leak rates have any effect on your conclusions?

A. None whatsoever.

Q. Thank you.

MS. MOORE: The Staff has no further questions.

JUDGE KELLEY: Okay.

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EXAMINATION BY THE BOARD

BY JUDGE KELLEY:

Q. Dr. Hitchler, I wonder if I could try one of my layman's questions on you. By that I mean I don't pretend to have any particular grasp of probability risk analysis. I even have to struggle for the phrase.

I was looking at your testimony at page 12, and you rely in part on PRA studies for your conclusions. And maybe you could just help me get some perspective on this.

Nine or ten years ago when the Rasmussen study came out, the Reactor Safety Study came out, it made a number of judgments about probabilities of different kinds of accidents, and then it was criticized by a lot of people, particularly the Executive Summary, as I recall, and that

WRBwb6

thereafter there was the so-called Lewis Committee formed, and the Lewis Committee did a rather extended critique of the study and concluded -- and I am oversimplifying here; but what I came away -- what I got out of the exercise was that the Lewis Committee said that these events, the probability of which was being predicted, really couldn't be predicted because you didn't have enough data, and that, therefore, these conclusions, at least as to some accidents, were not particularly valid. And I then inferred from that that probability studies of that nature were sort of interesting academic exercises but they weren't going to be the basis for licensing decisions.

With that in my mind, I see, from time to time now in the licensing context references to study of this kind, and I wonder why. And I note here that you have got only -- what? -- five instances of tube breaks in a lot of years of operation. Maybe that's part of the answer. But there is just this handful of isntances.

Mr. Eddleman brought out something that struck me, anyway, as significant, the fact that the oldest of the plants here is, maybe, fifteen years old, and most of them are -- have been on line for a year or two or three or five, and maybe as time goes on they'll get older and older and they'll wear out and there will be a lot more breaks.

So, can you give me some general feeling for

WRBwb7

why you're confident that this sort of probabilistic risk study can give us some comfort in licensing?

A. Well, I think there's a lot of value in these kinds of studies, obviously, so I take some exception to the discussion.

Q. Have things changed, or is this a different kind of study? Did Lewis not know what he was -- and his people, were they wrong?

A. No. Lewis and some of the other people that critiqued WASH-1400 had some very valid criticisms, which is one reason in particular why I chose the Italian reference design, and also the Millstone-III designs, which have specifically addressed all of the concerns they had from what I will call the technical basis side.

Now, the focus of my testimony, though, does not deal so much with what's the bottom line number, it deals more from a standpoint of the risk perspective as to what contribution these additional type of events have compared to what we use as our bounding case in the FSAR.

In other words, even if my-- I'm saying in the testimony at this point that the tube rupture events only represent 3 percent of the risks from the single tube -- the multiple tube rupture events only represent 3 percent of the risks of the singles. Even if I go up by an order of magnitude I'm still only just starting to approach what the

WRBwb8

singles are producing. So if I add large uncertainties -- and, by the way, the standard uncertainties in these calculations are in the half an order of magnitude or an order of magnitude range to bound the cases. We're still saying that the multiple tube ruptures represent only a small contribution -- or don't represent a major contribution in the area.

That's the first point, and it's risk perspective.

The second point here in terms of what I'll call confidence is what I alluded to in terms of the development of our procedures. Even though we're saying that these are not risk contributors, we have still looked at all of the potential scenarios that may exist via the event tree, the fault tree, the standard probabilistic tools, and identified what procedures may be worthwhile to give the operator, or what training may be worthwhile to perform a bounding, no matter what -- whether it's a multiple tube rupture or any other kind of an event, to find out what can happen even at very low frequencies, 10 to the -8, which we used for a cut-off, and then develop our recovery strategy for the operators in a fashion that will help them the most.

By the way, one reason why it's so important is that obviously we can't write procedures for every accident scenario possible. They were talking about a room bigger than this that would be filled with procedures, and the operator would never use them.

WRBwb9

So, therefore, the probabilistics have been used as an optimization process in terms of keeping the complexity down to a reasonable level for the operators, but also giving us maximum coverage for accidents, whether or not they're in the design basis or not.

So we have that level of confidence that we are helping here.

The other area is in terms of the probabilistic tools that we've used have helped in terms of -- strictly from Westinghouse's standpoint, but it also expands to the utilities' and the owners' groups, in terms of having a structured process for assessing how events can change once you get beyond single failure critiera in the normal licensing situation, as we have people that have been trained in possibly what would happen, therefore, in terms of manning our emergency response centers, and other functions such as this where we need people that can make those predictions and have a basis for extrapolating all the combinations that may exist, we have those tools in place.

So I don't want to pin this on just strictly the probability number. Basically we have a number of tools in getting the correct prospective and profile as to what is important in terms of the plant.

Q Thank you.

JUDGE KELLEY: Mr. Eddleman, have my questions or

Mrs. Moore's questions evoked any further questions on your part?

MR. EDDLEMAN: Well, I noticed in that NUREG 0651 something I want to ask about.

FURTHER CROSS-EXAMINATION

BY MR. EDDLEMAN:

Q In Table 7 the Prairie Island event, which is Number 4, I believe they give a leak rate of 336, and I am trying to figure out if that's another one that didn't come from that or what.

A The note here on that entry says that it came from a different document.

Q Did you have that note available to you when I asked you about the source of these documents -- of these numbers?

A Yes. In fact I mentioned that. As I recall, that was one of my responses, was that most came from 651 or like documents with the exception of entry Number 5.

Q Entry Number 5 is Ginna, and does that one actually come from the document that is referenced in Number 2?

A Yes.

Q All right.

As to these probabilities that you're talking about that Judge Kelley asked you about, has there been anything like the Lewis Committee that has looked at your PRAs and something outside the nuclear industry a-d the NRC, some kind of respected scientific review?

A How broad-ranging do you want to carry that? In other words we have been through a peer review process in England, in fact with very similar models with the United Kingdom Atomic Energy Authority and with their public inquiry on these issues.

We have also just completed the ACRS Subcommittees in terms of the Millstone 3 analyses, of which there was a peer review through Brookhaven and Lawrence Livermore Laboratories.

Q Well, I guess what I'm asking is has there been any sort of a blue ribbon panel or somebody who is not normally a nuclear contractor or something like that who reviewed this?

A Not these specific documents.

If the question is in terms of is this techrology being accepted in industries other than the nuclear industry, the answer is a definite Yes. Not only has in fact a lot of the technology sprang from the aircraft industry and is making significant further expansion in the petrochemical industry at this point, so these techniques are not unique to the nuclear industry.

It is just that the nuclear industry I feel has carried a torch over the last five years, taking it from the aircraft industry and now that torch is being moved into other areas now, other than nuclear.

Q If this torch is not correct, somebody might get burned, might they not?

A It is better to know your hazards.

Q I would agree.

Are there industries that use failure modes and effects analysis of what can go wrong, regardless of probability?

A That was the technical issue that was in high favor eight to ten years ago. The problem that they came up with in their analysis was that in any kind of a complex system, the failure modes and effects analysis became so overwhelming that you could not get a perspective as to what was going on.

So the fault tree techniques that we use here and the event trees for organizing them are what I call the next generation from the failure modes and effects analysis.

Q Well, fault trees and event trees were used, were they not, by Dr. Rasmussen and his NRC subordinates in '74?

A The technology was, an early form of the technology. There have been significant advances since then, revolutions in the models and techniques. And peer review.

Q And none of this is referenced in your testimony, is it?

A The reports that have the -- that I draw from in here are all in the public record, and the reviews are on the public record also.

Q But you didn't provide a reference in your testimony as to which of them you rely on, did you?

A Not specifically.

Q Thank you.

MR. EDDLEMAN: That's all.

JUDGE KELLEY: Is there redirect, Mr. O'Neill?

MR. O'NEILL: Thank you, your Honor.

REDIRECT EXAMINATION

BY MR. O'NEILL:

Q Mr. Hitchler, at one point in your oral testimony you indicated a maximum flow rate from a double-ended tube rupture of 800 to 900 gallons per minute.

At one point during cross-examination it was suggested that looking at a graph of flow rates from the FSAR that there might be a lower initial flow rate.

What impact would a lower flow rate from a tube rupture have on your conclusions in your analysis?

A Very conservative. In other words, the higher the numbers, the response times would be much shorter which means that if Harris has a number significantly below this that the core damage numbers would be much more improved than what we show. So it is conservative to assume the higher flow rates.

Q In answering Mr.Eddleman's many questions about whether proposed calculations that he suggested could be done, were you implicitly expressing a view as to the appropriateness or utility of such hypothetical calculations?

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A I was not expressing any view. I was answering the questions.

I feel that we have come up with a model for predicting tube rupture events. We have looked at the potential variations that may exist and come up with an optimal way for analyzing these events.

End 15

MR. O'NEILL: No further questions.

JUDGE KELLEY: Mr. Eddleman, anything else?

RECROSS EXAMINATION

BY MR. EDDLEMAN:

Q. When you said something could be done the same way you did it, any defects that were done in the calculation, if it were really done the same way you did it, the same way methodology used, would be the same sort of defects that there are in your own methodology, wouldn't they, as to probability calculations?

A. What do you mean by defects?

Q. Well --

MR. O'NEILL: Could I have the question repeated?

BY MR. EDDLEMAN:

Q. Well, to the extent that a probability calculation were done, including the ones that I asked you about, and they were done in accordance with your own methodology, they would be just as valid as your methodology, wouldn't they?

A. If they followed the same level of internal review and also there was the agreement that they would adhere to industry's guides that we have on this such as NUREG 2300, the PRA procedures, then I would say that it would probably be acceptable.

Q. Okay. Is there anything in the PRA procedures guide about calculating tube rupture probabilities?

A. There's a segment in there that talks about generating frequencies for initiating events and, also for the treatment of data and, also, as I mentioned, a very specific section that talks about adequate reviews and calculations.

Q. Now, are you saying that all your calculations and things in here don't do that sort of review before they were put in the testimony?

A. At this point, yes.

Q. Have they been checked before you took the stand?

A. Yes.

Q. Were you familiar with the results of those checkings?

A. I was familiar with the results. Again, we're talking a large amount of material.

Q. In your answer to Mr. O'Neill's question, were you suggesting that one could not validly make calculations in accordance with standard statistical procedures using the same data that you used or parts of it?

A. No.

Q. Okay.

A. The statement, as I understand it or as your question's implying is can I do the calculation? The answer is yes. My statement to Mr. O'Neill was that did I feel that it was prudent and going beyond the variations that we've already studied. The answer to that was no.

Q. All right. And, well let me say just that the results of those calculations could speak to themselves, couldn't they?

A. Yes, they could.

Q. As to the flow rate shown in the figure one from the Harris FSAR question's response, if the flow rate is as low as this, doesn't that show that an actual event, namely the Ginna event, has resulted in higher flow rates?

A. It could but there are differences in plants that we're talking about. My earlier discussion was that I will expect flow rates on a bounding basis to be in the 800 GPM range.

Now, for Harris, we're saying that it is -- in the case that we're showing the bounding case that was generated for the FSAR, and remember that bounding case has more than just the shearing of a pipe. There's also location, temperatures that are assumed, and there are a number of other constraints that must be looked at maximize the conservatism that we're using in this analysis. For the case presented in the FSAR which maximizes the dose calculations and other types of criteria, this was the flow rate.

Q. All right.

Shouldn't that analysis in the FSAR be a bounding analysis in the terms that you said?

A. It is.

Q. But you said in your testimony that an 800 to 900 gallon per minute flow rate would be a bounding rate for a plant like this, didn't you?

A. For virtually all plants.

Q. Okay. And had you actually reviewed this flow rate diagram or any flow rate data from the Harris FSAR when you prepared your testimony?

A. No. I had questioned the individual who had generated this material at Westinghouse to be assured that the analysis that I was using in the probabilistic assessments was bounding at the Harris plant.

Excuse me, I had that reversed. That the analysis that I was using bounded any flows that we would anticipate at Harris.

Q. And there was no pure review, or was there, to your statement that the likely flow rates of Harris would not be exceeded by tube ruptures that had been experienced?

A. I'm not certain what you mean by "would not be exceeded"? In other words, it is theoretically impossible for Harris to exceed certain flow rate conditions just because the tubes themselves are of a different dimension.

Q. Well, what is that theoretically maximal flow, do you know?

A. What I've heard is that the theoretical maximum for Harris is in the 640 GPM range.

Q. That's for a single tube, right?

A. Yes.

Q I'm trying to locate where you -- excuse me a minute. I'm trying to find something in your testimony.

JUDGE KELLEY: Let me get it clear in my own mind. I see this recross as an opportunity for you to ask followup questions on top of Mr. O'Neill's redirect, essentially. But it seems to be becoming rather extensive.

MR. EDDLEMAN: Well, I think Mr. O'Neill was asking about a different thing with respect to this document than I was asking about. I'm trying to tie it back to the original thing which is, does the --

JUDGE KELLEY: Well, my point is that your question under the rules as I understand, ought to relate to what Mr. O'Neill was talking about on the theory that Mr. O'Neill got into something new. It's not just a springboard for further cross examination.

MR. EDDLEMAN: Okay. Let's see if I can relate this back to Mr. O'Neill. If not, I will just drop it.

JUDGE KELLEY: All right.

BY MR. EDDLEMAN:

Q Did you understand my question about the flow rate from one of these ruptures to relate to the probability analysis of the flow rate and its consequences?

A I'm not certain in what point.

Q All right.

I think we can let the record speak for itself as to what he answered earlier. So that's all I've got.

MR. O'NEILL: Mr. Chairman, I have one question I think will clarify something.

JUDGE KELLEY: All right.

FURTHER REDIRECT EXAMINATION

BY MR. O'NEILL:

Q. Mr. Hitchler, are you aware of any difference in diameter between the steam generator tubes at Ginna and the steam generator tubes at Harris?

A. Yes, I am.

Q. And do you know which of the two steam generators have a larger diameter tube?

A. Ginna would have a larger diameter.

Q. Would that explain the difference between the flow rates between the two?

A. Yes.

Q. Thank you.

JUDGE KELLEY: All right. Mr. Hitchler, that brings us to the end of our questioning process. We appreciate your attention and your answers. Thank you very much, you're excused.

(Witness excused.)

JUDGE KELLEY: Does the Staff have a panel or sequential witnesses?

MRS. MOORE: It's a panel, your Honor.

JUDGE KELLEY: Why don't we call your witnesses and have them sworn and get a summary if they have one, then we can take a break before we get into cross, okay?

MS. MOORE: Okay.

The Staff calls Mr. Ledyard B. Marsh and Mr. Herbert F. Conrad.

Whereupon,

LEDYARD B. MARSH

and

HERBERT F. CONRAD

were called as witnesses and, having been first duly sworn, were examined and testified on their oath as follows:

DIRECT EXAMINATION

BY MRS. MOORE:

Q. Mr. Marsh, would you please state your name, position, and business address, for the record?

A. My name is Ledyard Bruce Marsh, I'm a Section Leader in the Reactor Systems Branch at the NRC. My address is the NRC in Washington, D. C.

Q. Mr. Conrad, would you please state your name, position and business, for the record?

A. My name is Herbert F. Conrad. I'm a Senior Materials Engineer at the Nuclear Regulatory Commission at Bethesda -- Washington, D. C.

Q. Gentlemen, do you have before you a document entitled NRC Staff Testimony of Ledyard B. Marsh and Herbert F. Conrad, regarding Joint Contention 7, Part 4?

A. (Witness Marsh) Yes.

A (Witness Conrad) Yes.

Q. Did you prepare or participate in the preparation of this testimony?

A. (Chorus of yes.)

Q. Do you have any additions or corrections to the testimony?

A. (Chorus of noes.)

Q. Do you adopt this as your testimony in this proceeding?

A. (Chorus of yes.)

Q. Is the testimony true and correct to the best of your knowledge, information, and belief?

A. (Chorus of yes.)

MRS. MOORE: Your Honor, copies of this testimony have been served on the Board and the parties and delivered to the court reporter. I move that the testimony and the attached professional qualifications be admitted into evidence and bound into the record as if read.

JUDGE KELLEY: Motion granted.

(The joint testimony of Staff witnesses Marsh and Conrad regarding Joint Contention VII (Part 4), plus Attachments 1 and 2, being the professional qualifications of Witnesses Marsh and Conrad, follows.)

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of CAROLINA POWER AND LIGHT COMPANY AND NORTH CAROLINA EASTERN MUNICIPAL POWER AGENCY (Shearon Harris Nuclear Power Plant, Units 1 and 2)	Docket Nos. 50-400 OL 50-401 OL

NRC STAFF TESTIMONY OF LEDYARD B. MARSH AND HERBERT F. CONRAD REGARDING JOINT CONTENTION VII PART (4)

Q1. Mr. Marsh, please state your name, affiliation, and position.

A1. My name is Ledyard B. Marsh. I am Section Leader in the Reactor Systems Branch, Division of Systems Integration, NRC Office of Nuclear Reactor Regulation.

Q2. Have you prepared a copy of your professional qualifications?

A2. Yes. A copy of my professional qualifications is attached to this testimony as Attachment 1.

Q3. Mr. Conrad, please state your name, affiliation, and position.

A3. My name is Herbert F. Conrad. I am presently a Senior Materials Engineer in the Inservice Inspection Section of the Materials Engineering Branch, Division of Engineering in the Office of Nuclear Reactor Regulation.

Q4. Have you prepared a copy of your professional qualifications?

A4. Yes. A copy of my professional qualifications is attached to this testimony as Attachment 2.

Q5. What is the purpose of this testimony?

A5 The purpose of this testimony is to address Joint Contention VII, Part (4) which asserts that the Applicant has failed to demonstrate that the steam generators are adequately designed and can be safely operated in light of existing tube failure analyses. Specifically, this testimony addresses the need for the Applicants to address multiple steam generator tube ruptures as a design basis event in their tube failure analysis.

Q6. Have the Applicants analyzed the consequences of a steam generator tube rupture accident?

A6. Yes. The Applicants' analysis is contained in Chapter 15.6.3 of the FSAR, and in the responses to various Staff questions.

Q7. Please describe the analysis and results.

A7 The Applicants' analysis, supplemented by the responses to Staff questions, assumes a double-ended guillotine break of a single steam generator tube combined with an assumed complete loss of off-site power. Also, the analysis assumes no operator action for 30 minutes, the initial primary coolant iodine concentration at the worst allowed by the Technical Specifications, and the initial steam generator tube leakage at the maximum allowed. The analysis evaluated the systems performance, operator actions and off-site consequences. The Applicants' analysis demonstrates that the radiological limits of 10 C.F.R. Part 100 are met. However, Applicants are being required to substantiate selected assumptions of that analysis.

Q8. Have the Applicants postulated a multiple tube rupture as a design basis accident?

A8. No. The Applicants have not postulated multiple double-ended guillotine break tube ruptures, as a design basis accident. The Staff does not require that multiple, double-ended guillotine ruptures be postulated within the design basis for a number of reasons. These are as follows:

(1) The Staff believes that the likelihood of multiple, double-ended guillotine tube ruptures is exceedingly low, although not quantified for the Shearon Harris plant.

(2) The assumption of a single, double-ended guillotine tube break covers a spectrum of smaller, more probable leaks, including the leakage from a few tubes.

(3) The scenarios postulated for design basis accidents were never considered to represent an expected event, but rather are considered to be stylized scenarios designed to bound the consequences of a spectrum of similar, but less severe events.

Thus, while an operating reactor event may show that any one assumption in an accident analysis might be exceeded, it is the integral conservatisms in the analysis that assure that the FSAR analyses will be bounding. The acceptability of this approach has been substantiated by the four domestic steam generator tube rupture accidents in which the overall consequences were all less severe than the FSAR analyses.

However, as part of the Staff's continuing review of the Standard Review Plan and of the Ginna SGTR accident, a thorough review of the SGTR assumptions, analyses and inherent conservatisms is planned.

Q9. What surveillance measures will be implemented at Shearon Harris to minimize the likelihood of a multiple tube rupture accident?

A9. The Shearon Harris plant technical specifications will require periodic inservice inspection of the steam generator tubes and the steam generator secondary side water will be monitored for leakage from the primary side. Eddy current testing of the tubes is routinely required every 12 to 24 months. In the event of a tube leak exceeding the technical specification limit of 500 gallons per day per steam generator, the plant is required to shut down and to perform an unscheduled inspection as well as plug the leaking tube. Eddy current indications in excess of 40% through wall degradation are required to be plugged, except for tubes in the preheater section.

In this manner, the integrity of the steam generator tubes is systematically monitored to uncover any defect or degradation before tube degradation becomes serious. The limits on allowable primary to secondary leakage are designed to assure that a tube leaking at a rate equal to or less than the limit will retain adequate integrity against rupture. Experience has shown that where serious flaws have gone undetected, the usual consequence is a small leak of manageable size. In such cases the plant is shut down in an orderly manner for tube plugging.

Q10. What would be the likely consequences of a multiple tube rupture accident?

A10. In the unlikely event of a multiple tube rupture accident, as either an initiating event or as a consequence of another design basis accident, various calculations performed for another Westinghouse PWR have shown that the existing safety systems automatically respond to bring the plant tc a stable condition, allowing the operator sufficient time to assess the accident, and take the appropriate actions. Primary coolant natural circulation, steam generator auxiliary feedwater and the injection of additional coolant from the high pressure safety injection system were sufficient to remove core decay heat and to keep the core covered and cooled. Calculations performed by Westinghouse, in support of the new emergency operating guidelines, have shown similar results.

Although these calculations were not performed for the Shearon Harris plant, the Staff compared the parameters most important in tube rupture accident scenarios (e.g. power, volumes, temperature, and safety injection system characteristics) and concludes that these calculations would bound the Shearon Harris plant.

Even though the Applicant has not postulated multiple tube rupture accidents within the design bases, the new Westinghouse emergency operating procedures, which the Applicant has committed to utilize, will enable the operators to deal with a variety of beyond design basis tube rupture accidents. For example, the emergency procedures deal with single and multiple tube rupture accidents as initiating events, tube rupture accidents combined with a loss of secondary integrity and tube ruptures combined with a variety of equipment malfunctions. The Shearon Harris operators will be trained to recognize and manage such events.

In summary, the Staff believes the Shearon Harris plant has an inherently large margin to safely accommodate multiple tube ruptures. Moreover, in the unlikely event of a multiple tube rupture accident, the Staff believes that the safety systems and operator actions will ensure the core always remains covered and cooled, and the overall consequences will be acceptable.

Q11. In summary do you believe that the Applicant should be required to consider multiple tube rupture accidents as a design basis accident?

A11. No. The Staff believes the existing design basis SGTR scenario defined in the SRP and analyzed in the Applicants' FSAR is acceptable and will bound a variety of similar less severe scenarios. Past operational experience is consistent with this conclusion. Furthermore, the Staff believes the combination of preventative measures afforded by the steam generator tube design, inspection, plugging and leak rate criteria coupled with the thermal hydraulic calculations demonstrating that the existing plant safety systems can mitigate a variety of multiple steam generator tube rupture accident scenarios, further confirm that the Applicants need not include these multiple failure accidents in the plant's design basis.

Attachment 1

Statement of Professional Qualifications

Ledyard B. Marsh

I am employed as a Section Leader in the Reactor Systems Branch, Division of Systems Integration, Office of Nuclear Reactor Regulation. My responsibilities include supervising the safety reviews of the reactor coolant, emergency core cooling, accident and transient analyses as well as other reactor systems which are assigned to me during the review of nuclear power reactor license applications or safety analyses to support proposed operating reactor technical specification changes.

I graduated from the University of Oklahoma in 1970 with a Bachelor of Science in Electrical Engineering. In 1976, I received a Masters of Science degree in Nuclear Engineering from the University of Washington.

From 1970 to 1974, I was an officer in the Navy Nuclear Power Program. I attended a year of formal training in the design and operation of the Navy surface ship nuclear propulsion plant. I was then assigned to nuclear powered heavy destroyer, USS California, where I took part in the propulsion plants construction, testing and operation.

In August, 1976 I accepted employment with the Nuclear Regulatory Commission in the Reactor Safety Branch. I reviewed safety analyses to support licensee proposed ECCS design modifications and technical specification changes. In late 1979 and early 1980 I supervised the review of the three domestic steam generator tube rupture events and was the principal author of NUREG-0651, "Evaluation of Steam Generator Tube

Rupture Events." In my present position as Section Leader in the Reactor Systems Branch, I have been involved in the development of plant specific and generic recommendations as a result of the Ginna SGTR as well as the other domestic SGTRs and have supervised the Division of Systems Integration technical input into the report presenting the resolution of USIs A-3, 4, 5, NUREG-0844. Also, I supervised NRR's review of the need for pressurizer PORVs for the new Combustion Engineering PWRs, and the development of the report presenting the staff's review, "Evaluation of the Need for a Rapid Depressurization Capability for CE Plants", NUREG-1044.

U.S. NUCLEAR REGULATORY COMMISSION
HERBERT F. CONRAD
PROFESSIONAL QUALIFICATIONS

My present position is Senior Materials Engineer, Material Engineering Branch, Office of Nuclear Reactor Regulation. In this capacity I am responsible for technical safety review and evaluation of materials used in the construction of nuclear power plant components. Specifically, the responsibilities include evaluation of materials application, heat treatment, fabrication, inspection and corrosion control. I am a former member of the American Society of Mechanical Engineers Nuclear Code Committee Subgroup on Fabrication and Examination (Section III).

I hold a MS in Metallurgy (1959) and a BS in Mechanical Engineering (1957) from the Massachusetts Institute of Technology. I am registered by the State of California as a Professional Engineer in Mechanical Engineering and in Metallurgical Engineering with more than 24 years of professional experience. I am a member of the American Society for Metals (ASM). I have several publications in metallurgy, the most recent is a contribution to the ASM Metals Handbook, Volume 10, Failure Analysis (ASM, 1975).

I have been with the Nuclear Regulatory Commission since February 1973, two years of which were as a loan employee on detail from the University of California. Prior to my assignment to Washington, I was employed by the Lawrence Livermore Laboratory of the University of California as a Metallurgist.

BY MRS. MOORE:

Q Mr. Marsh, would you please summarize your testimony?

A (Witness Marsh) Yes. For the summary, I would like to read from the response to question 11. "The Staff believes that the existing design basis steam generator tube rupture scenario defined in the Standard Review Plan and analyzed in the Applicant's FSAR is acceptable and will bound a variety of similar less severe scenario. Past operational experience in consistent with this conclusion. Furthermore, the Staff believes the combination of preventative measures afforded by the steam generator tube design, inspection, plugging and leak rate coupled with the thermohydraulic calculation demonstrating that the existing plant safety systems can mitigate a variety of multiple steam generator tube rupture accident scenarios, further confirm that the Applicants need not include these multiple failure accidents in the plants designed basis."

MRS. MOORE: Your Honor, the witnesses are now available for cross examination.

JUDGE KELLEY: Okay. Why don't we take, let's say, no more than a 10 minute break here and then we will go direct to cross.

End 16

(Recess.)

JUDGE KELLEY: We will turn to Mr. Eddleman, or is it going to be Mr. Runkle?

MR. RUNKLE: I had a question of clarification, just on the -- when the last witness was on here.

Now when they had a break in place and the attorneys had talked to him about his response, I have never seen that in trials before. Is that common practice in NRC proceedings, or should we object to that, or what?

JUDGE KELLEY: I suppose you could. I don't think it is common, as I understood it. It might get a little academic in the sense that they are entitled to talk to their witness in breaks. They can go out in the hall and tell him something, so what's the difference if they want to tell him something briefly in place. It just saves some time I think.

MR. RUNKLE: I was just curious. I was so surprised I didn't object.

JUDGE KELLEY: I think if that sort of thing was used as a device for coaching, but I don't think-- That's the only thing that occurs to me. I don't see any indication of that here.

CROSS-EXAMINATION

BY MR. EDDLEMAN:

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Q Gentlemen, I believe your Counsel asked you if you prepared or participated in the preparation of this testimony.

What does it mean to participate in the preparation

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of testimony?

A (Witness Marsh) I can answer for myself.

I prepared, myself, the testimony here related to the systems performance and analyses, so in that sense "participation" means I directly prepared it.

Q Which questions and answers are those?

A Rather than going through them and looking for questions and answers, because I think there are some aspects in both of our areas in different questions, let me just answer by saying Mr. Conrad prepared testimony related to the metallurgical inspection and plugging water chemistry, et cetera, and I prepared the analyses questions and the procedural questions.

Q I may address a question to either of you but if the other one has something to add, please just go ahead.

Do either of you gentlemen know whether there is a requirement in the tech specs for Shearon Harris as to the amount of steam generator tube wall degradation that is allowed before the leak has to be plugged?

A (Witness Conrad) Yes, the plugging limit in the proposed technical specification would be 40 percent.

Q Okay.

The tech specs are things that the NRC can enforce if they are violated, are they not?

A That's correct.

Q Is there anything in the NRC's own rules that specifies any limit tighter than that, that is, anything less than 40 percent as a criteria?

A There is nothing in the rules or regulations or guides that would specify a percent greater than 40 percent.

Q Would any of it specify a different level than 40 percent?

A It is really site-specific so regulations don't address it as a percent of the wall. It tells them the general criteria for establishing the minimum wall.

Q Okay.

And what are those criteria?

A It is simply that you can't allow the wall to be reduced to an extent that a burst would be possible under ordinary operating conditions or accidents. And then there are also criteria that ask for conservatisms to be added to the minimum wall to arrive at the plugging limit.

In other words, the plugging limit will be quite a bit smaller than the calculated minimum allowable wall.

Q Do you mean that the plugging limit will be quite a bit smaller amount of degradation or corrosion of the wall than the calculated minimum?

A The tube will have to be plugged at a smaller amount of degradation than would cause you to approach the actual minimum allowed wall thickness before you would have a break.

Q Now that you say is set forth in the rules?

A It is a Regulatory Guide.

Q That's a Reg. Guide.

Do you know what Reg. Guide that is?

A 1.121.

Q The general design criteria that you were talking about before, those are actually in the rules, are they not?

A The general design criteria are in 10 CFR, yes.

Q Now if the criteria are supposedly such that the tube wall condition should not be allowed that made a burst possible--

First let me ask you, is there a distinction in your mind between a burst and the kind of rupture that is talked about later on in this testimony?

A The burst or minimum wall to failure, let's say, -- that I am referring to is based upon a calculation of the material strength.

Q So if the material strength is so many pounds per square inch, you can figure out what the volume of the material is that is holding back the pressure and if that is not enough it will burst?

A That's correct.

Q And is that calculation usually made with the specified strength of the material? In other words if it is

70,000 psi material, do you use 70,000 pounds in that, or do you take something off for conservatism?

A. I don't -- I'm not in the branch that does the detailed review of the plugging criteria, but I can speak in my general understanding of it. And I believe that's correct.

Q. Okay. Well, now could the flow rate through a burst of this type be any greater than you get out of this guillotine break that's discussed in this testimony?

A. (Witness Marsh) Let me try to answer that. To the best of my knowledge, we have not seen a case where the flow rate in any tube rupture has exceeded that which has been predicted in the safety analysis. We have done -- we've not only compared the Ginna event to the Ginna FSAR, we've also done confirmatory calculations by National Lab to see if, in fact, the break flow that was experienced would have exceeded what we would have predicted. And we did not see that situation.

Q. Now, I asked you a slightly different question. Let me try again.

In a rupture, a bursted tube, as Mr. Conrad defined it, is there any difference between the flow rate that's possible under that burst condition and the flow rate that's possible under this guillotine break condition that's discussed in the testimony?

A. The burst that was experienced at Ginna, that is, a fishmouth type of opening in the tube, could approach the guillotine break flow rate. Does that answer your question?

Q. I think it does. Let me follow with this: Does that mean that the burst flow rate is less than or in the worst case equal to the guillotine break flow rate?

A. Yes.

Q. Okay. Now, the criteria, as I understood it, was that you couldn't have all conditions where a burst was possible at normal operating or accident conditions. Does that criterion mean a physical burst only, you can't actually have the two burst?

I'm asking Mr. Conrad, but if -- either of you can answer.

A. (Witness Conrad) As you correctly stated, that means that the remaining cross section or area, as you call it, left in the tube wall does not exceed the minimum yield ultimate strength of the tube.

Q. So under those conditions if you applied the normal pressure differential across then it would burst, right?

A. Well, experiments have shown that real -- simulated tubes with cracks in actual tests have had to have been pressurized at higher pressures than a calculation. So the calculations that the plugging limits are based on seem to be more conservative than real life.

Q. Now, when you say simulated tubes, do you mean that there are tubes like the tubes that would be installed in the steam generator or are they a simulation of such a tube, or --

A. I'm sorry. I mean the crack or defect was simulated in a tube that, for all intents and purposes, is the same as that in a steam generator.

Q. The same as one that would be installed new, is that right?

A. That's correct.

Q. And not necessarily achieved that it had actually been exposed to the radioactivity and operating conditions in the steam generator for a number of years?

A. No, that's the reason we put the simulator defect in to simulate known degradation process. Radiation has no effect on it.

Q. The defect -- is it placed in physically, is it cut into it with a tool, or --

A. It can be cut in with a tool, or a more sophisticated machining method, electrospark discharge. They've all been tried. The testing includes various configurations of simulate defects to try to bound the real thing.

Q. The test would include actual or accelerated corrosion on the tubes themselves?

A. None of the tests have been with actual defects from the corrosion process. They've all taken what we find in a corroded tube and try to approach that with these various machines.

Q. The criterion though that you can't have wall conditions where a burst was possible at Ginna a tube actually burst, didn't it?

A. That's right.

Q. So although this criterion might have been theoretically met by that plant in its licensing phase, it didn't work out that way in practice, at least in one instance?

A. I can't recall the analysis of the burst tube, if there was one done but it was quite possible that the loose part had damaged the thickness in excess of the plugging limit. I'm not sure, though.

A. (Witness Marsh) Let me add to that. I don't want you to think that we are saying that there will never be a tube rupture at this plant or another plant. What we're trying to say is that because of these various inspection design water chemistry et cetera, we believe we are going to minimize the chance of that occurring. There have been many plants operating for many years that have not had tube ruptures. So I'm not trying to say that there will never be another tube rupture to occur. It may occur. And should it occur, that the reason we ask Applicants to provide safety analyses, showing that the commission's acceptance criterias are not violated, as this plant has done.

Q. Okay. Have you actually received those acceptance criterias, reviewed them?

A. Yes, I have. It's in Standard Review Plan 15.6.3.

Q. Let me ask both of you again what NRC requirements or regulations there are in tech specs for Harris, if you know, concerning the water chemistry to be used in the steam generators?

MRS. MOORE: Your Honor, I would like to object to the question. I believe I heard Mr. Eddleman say "rules or regulations in tech specs"?

MR. EDDLEMAN: Let me split it into two questions. I think that's a good suggestion.

BY MR. EDDLEMAN:

Q. Gentlemen, is there anything at the Harris tech specs, to your knowledge, specifying or limiting the water chemistry to be used in the steam generators at Harris?

A. (Witness Conrad) I can answer that. No, not in the tech specs.

Q. Is there anything in NRC rules or regulations specifying the water chemistry, which the steam generators at Harris would have to use?

A. The Standard Review Plan gives the criteria for water chemistry.

Q. And what are those criteria?

A. They are again, general criteria. They essentially ask the operator to have a program that is as good as the state of the art.

Q. Well, in interpreting that, would an operator be bound for enforcement purposes by some current interpretation by the state of the art by the Staff?

A. Well, each plant at Harris gets a review by the chemical engineering branch who are the people responsible for reviewing the water chemistry program. And in the case at Harris they made the finding that their water chemistry program met our -- I won't say requirements -- but, met our criteria.

Q. Okay.

A. (Witness Marsh) Let me add to that if I can, please. It is my understanding that they, by the Standard Review Plan, must have procedures for a water chemistry program. And if a licensee or applicant doesn't adhere to his procedures, he can be cited.

Q. Right. Now, when they want to change their procedures, would they have to get approval from the Staff to do that?

A. I am not the expert in this area, but let me try. Since the water chemistry program is part of the Standard Review Plan and since, I believe, the chemical engineering branch has to review the water chemistry program, then if they wanted to change that water chemistry program, I believe they would have to ask the Staff how to do a 50-59 review themselves, and determine if there is no interviewed safety question or ask the Staff for permission to change the procedures.

Q. Okay. 50-59 refers to a part of 10 CFR?

A. Yes, that's right.

Q. Okay.

Let me ask you this: Did either of you gentlemen participate in the generation of those questions on the FSAR numbered from 450?

A. I'm sorry, can you help me on 450? I don't know what 450 means?

MR. EDDLEMAN: If your Counsel will permit, I will show you the same document I showed CP&L's witness.

MRS. MOORE: I have no objection.

(Eddleman at the witness table.)

MR. EDDLEMAN: This is the transmittal letter of answers to some of these questions.

(Witness Marsh reviewing document.)

MR. EDDLEMAN: I think we may have to look into the attachment to see there is a question here. (Indicating.)

A. (Witness Marsh) In answer to your question, I did not have any preparation of these questions. They were in the review of these responses, but I've seen questions similar to this and responses similar to these.

Q. Now, the question 450.4 here has a number 15.5.3. Would that be a Standard Review Plan reference?

A. Yes, I believe that that that is -- the question discusses steam generator temperature and the reference is to 15.5.3. I believe that is 15.6.3. It is not easy to see and that is the Standard Review Plan reference number.

End 17

18 fls.

Q And the question requests additional information on steam generator tube rupture analysis, does it not?

A Yes.

Q Now given that you gentlemen didn't generate this question, did either of you have any responsibility for the analysis of the FSAR on steam generator tube rupture for Harris?

A As I stated in my response to A-1, I am a section leader in the reactor systems branch and at one point there was a reviewer working for me who had the responsibility for Shearon Harris.

Now the reviewer in our branch is not under my direction, so I can't say whether those questions were under me or not. I don't believe they were.

So I did not have any responsibility to my knowledge in reviewing the Shearon Harris steam generator tube rupture analysis.

Q Okay.

The answer to question number seven on page two in the second line there it says:

"The Applicants' analysis, supplemented by the responses to Staff questions...," now the Staff questions are the ones about steam generator tube rupture, is that correct?

A That's correct.

agb/agb2

Q It then says it "...assumes a double-ended guillotine break of a single steam generator tube..."

A That's correct.

Q And then it says: "...combined with an assumed complete loss of off-site power."

A That's correct.

Q Now is that complete loss of off-site power considered to be the most limiting single failure --

A Yes.

Q -- for a tube rupture?

A Yes, it is. That is specified in the Standard Review Plan as one of the analysis requirements.

Q Now the double-ended guillotine break that you are talking about there, this is essentially the same kind of break that is referred to in the Applicants' testimony, is that right?

A There was a lot of Applicants' testimony but he referred to double-ended guillotine breaks at Shearon Harris also, so in that regard, yes.

Q I wasn't sure he had used the word "guillotine break." I was trying to see if there was a difference.

A I guess I don't remember if he said "guillotine."

Q Okay. Let me just ask you this:

The break that is assumed here in answer seven, is the equivalent of just taking the tube and slicing it completely through at one point and just pushing the ends apart, right?

A. Yes. The important thing is it is a double-ended break and it is an offset break so the two flows do not interfere with each other to get the maximum flows.

Q. So it is the break that produces the maximum flow out of the ruptured tube?

A. That's correct.

Q. Okay.

Are you gentlemen familiar with the stipulation between the Joint Intervenors and Applicants on Joint Contention 7 concerning the analysis of steam generator tube rupture?

A. Yes, I am.

Q. That analysis is the one that is still under review?

A. That's correct.

Let me make sure I answered properly. The stipulation for the settlement is that the Applicant must reperform a safety analyses of the steam generator tube rupture and substantiate the operator action times assumed in that analysis.

Q. The stipulation might go a little farther than that about the action times, but --

A. It also says you cannot assume operator action within 30 minutes, I believe.

Q. I believe so, too.

Anyway what I am saying is is it the Staff or the stipulation or is it both that requires Applicants to substantiate selected assumptions of that analysis?

A. It is the Staff initially and it is now the stipulation in the license condition.

Q. Okay.

And is that analysis subject to your review, members of your branch?

A. Yes, it is. Not only my branch, it also comes into at least one other branch. That other branch is the branch that reviews the off-site consequences of this event.

Q. Which assumptions are the Applicants being required to substantiate, or have those been selected yet?

A. It is the 30-minute isolation time, whatever isolation time is assumed in that analysis has to be substantiated and the assumption that there will be no steam generator overfill in that analysis.

Q. And the assumption of no overfill?

A. That's correct.

Q. That is, no overfill before isolation, is that right?

agb/agb5

A. That's correct.

Q. Okay.

The responses to the various Staff questions that are referred to in answer six on page two, those questions would be ones that are referenced to Chapter 15.6.3 of the FSAR?

A. That's correct. I'm not sure if the responses I referred to in my testimony are the same as you showed me. I would need to look at those more carefully.

Q. I wanted to ask you if those were the same ones, but if in fact the question identifies 15.6.3 as the source, were those the questions that you were referring to?

A I am not sure it is referred to by referencing 15.6.3. It is normally a 440 series question, so -- You showed me a question and the response that had in parentheses 15.6.3. I'm not sure all of the questions and responses associated with steam generator tube rupture have that in parentheses.

Q. Okay.

You also state:

"The Applicants' analysis is contained in Chapter 15.6.3 of the FSAR, and in responses to various Staff questions."

Which specific responses, if you have a list or something like that, did you have in mind when you wrote this answer?

A. I have responses to questions -- I don't have it right with me -- it was in a letter from CP&L to the Staff in the early part of July of this year.

Q. The early part of July '84.

A. Yes.

Let me hedge a bit: I believe it was this year. I'm sorry, I don't recall whether it was this year or last. I recall it was July.

Q. Let's turn over to the next page, if we might, answer eight at the top of that page, it says:

"The Applicants have not postulated multiple double-ended guillotine break tube ruptures as a design basis accident."

Could you have a multiple tube rupture in which not all of the breaks were double-ended guillotine breaks?

A. I would never say never. I would hesitate in agreeing with you that you could though.

Q. What is the source of your hesitation?

A. Later on in this response we talk about double-ended guillotine tube ruptures being extremely low, the chance of that occurring. That is Mr. Conrad's area talking about the inspection area, et cetera, these things. So I would just not want to admit readily that you could have one of these events without trying to quantify what the probability is because we haven't done that. We still think it is a low likelihood event.

Q All right. Well let me perhaps ask Mr. Conrad, if I may, and please feel free to respond also:

The types of tube ruptures that actually have occurred aren't all guillotine breaks or the flow equivalent of them, are they?

A. No, the only one that approached the double-ended guillotine break was the Ginna tube rupture. All of the others were less than what you would predict from a double-ended guillotine break.

Q These predictions of the double-ended guillotine breaks are the ones that are in NUREG 0651 as taken from the FSAR analysis, is that right?

A. I think you are referring to Table 10 where it had two columns for each plant and it showed the FSAR number and the actual?

Q Yes.

A. Yes, those were taken from the FSAR.

Q And you were, as the statement in your testimony states -- or I think in your attachment, you were one of the authors of 0651, were you not?

A. That's right.

Q I guess what I am trying to get at is if you just

agb/agb8

set aside for a moment the question of the probability of the event but just if you assume that it was possible if you have two or more tubes rupture would all the ruptures have to be double-ended guillotine breaks?

A. No -- I'm sorry, I don't know what you mean by "have to be."

Q. All I am trying to do is separate the question of the probability of the multiple rupture event, which you say you hadn't calculated but you believe is low --

A. Right.

Q. -- and the possibility of, on ruptures, where not all of them are double-ended guillotine breaks.

A. Certainly you could, as I state in two, the paragraph just below:

"The assumption of a single, double-ended guillotine tube break covers a spectrum of smaller, more probable leaks, including the leakage from a few tubes."

So that means that this double-ended guillotine break is, in our minds, a very bounding conservative calculation. And even if one were to postulate a multiple tube rupture, then that double-ended guillotine break of a single tube would, in our minds, cover a lower probability event which could be some combination of small tube leaks.

Q It would be at least possible though, would it not, to have more than one tube break in such a way that you could exceed the flow of a single double-ended guillotine break?

A Yes.

Q Okay.

Now you state in part three of that answer there on page three:

"The scenarios postulated for design basis accidents were never considered to represent an expected event....," but are -- and I am skipping over here -- "...designed to bound the consequences of a spectrum of..." events.

Now is that the general criterion for setting up a design basis accident?

A Generally speaking that is true. The Standard Review Plan analyses are not meant to actually track real situations, real -- what we consider to be the more likely situations. Generally they are supposed to bound what may actually occur in the plant. Past experience has shown that to be true.

Q Okay.

Well for example, did the design basis accident for Three Mile Island Number 2 include the disintegration of most of the core?

A. I am not a TMI 2 expert but I am sure that it did not, but that doesn't mean that you could not have accidents that are beyond the design basis.

Q. Okay.

So what you are saying is even though the design basis accident is designed to bound what can actually happen, that doesn't mean that you can't actually have something beyond design basis occur?

MRS. MOORE: Objection, your Honor. The witness just answered that question.

JUDGE KELLEY: Comment, Mr. Eddleman?

MR. EDDLEMAN: I was just trying to rephrase it, I will accept his past answer.

JUDGE KELLEY: All right.

BY MR. EDDLEMAN:

Q. You go on to say, do you not that:

"...it is the integral conservatisms in the analysis that assure that the FSAR analyses will be bounding."

A. That's right.

Q. Okay.

And then you say:

"...the overall consequences" -- of the four domestic steam generator tube rupture accidents -- "...were all less severe than the FSAR analyses."

agb/agb11

What was the FSAR leak rate for Ginna, do you know?

A. I'm sorry, I don't recall exactly. I believe it was in the 700 to 750 gallons per minute range, but that is a recollection.

Q. Subject to check.

A. I don't have the -- I'm sorry, it is in Table 10 -- no, I don't have that FSAR number here with me.

Q. But that is something you could check against the Ginna FSAR, could you not?

A. Yes.

Q. Let me ask you this, because some of the Applicants' numbers didn't seem to agree with your numbers in 0651?

The Applicants' testimony, table seven, do you have that available to you?

A. I'm sorry, not here.

MR. EDDLEMAN: May I show it to him?

MRS. MOORE: Yes.

JUDGE KELLEY: Sure.

(Mr. Eddleman at the witness table.)

BY MR. EDDLEMAN:

Q. I want you to ignore my marking here but the rate that is shown here for Ginna --

JUDGE KELLEY: Do the Applicants have an FSAR on the premises?

MR. O'NEILL: Not a Ginna FSAR.

JUDGE KELLEY: That figures.

MR. EDDLEMAN: I thought you guys were the lawyers for that plant, too.

MR. O'NEILL: I believe that is what he is giving him, Mr. Chairman.

WITNESS MARSH: It says 634 gallons per minute with a footnote two which says that it comes from responses to long-term commitments, Ginna re-start SER.

This reference I don't have, so I don't know.

BY MR. EDDLEMAN:

Q But that is what it says here?

A (Witness Marsh) Yes.

Q Now what I wanted to ask you -- You can keep looking at this if you like.

One page back do you have a recollection or any other information available to you or with you that gives a leak rate for that Ginna accident?

A I have NUREG 0909 with me. I don't recall what the number there is but I believe there is a leak rate given in 0909.

Q Okay.

NUREG 0909, is that a distinct document from the one that is referenced in reference two here, to your knowledge?

A. Reference two sounds like it is NUREG 0916. which was an evaluation the Staff did to see if the licensee had properly taken remedial measures and done proper analyses to allow the plant to restart. It was, I believe, called the restart FSAR. 09 was an evaluation that was done by the Staff evaluating the tube rupture itself, the Ginna tube rupture itself, without drawing any conclusions; it was just a fact-finding NUREG.

Q. Do you have any recollection of what the leak rate at Ginna was, yourself?

A. I believe it was on the order of 634 gallons per minute which is referred to in the testimony, but I believe it was slightly higher, not significantly, like 650 or something like that. I just don't recall exactly.

Q. Okay.

But you believe it was slightly higher than 634?

A. Yes. But let me say that 0909, the NUREG that I have with me which may give that leak rate, was the Staff's first analysis of the tube rupture itself. And I know there were analyses that were done after that point. And the 0916 number that Mr. Hitchler's testimony has may come from 0916 which may be a more accurate analysis.

Q. Have you reviewed either of those analyses in connection with preparing your testimony?

A. No, I have not.

Q Let me ask you this:

The Ginna rupture was the worst rupture that has happened in the United States in steam generator tubes so far in an operating a nuclear plant, isn't it?

A. It resulted in the highest leak rate, if that is what you mean by "worst."

Q Okay.

And did it also result in the highest off-site release of radioactivity or did another one do that?

A. No, I think that is accurate. But I was not involved in the radiologic consequence assessment of Ginna. I am speaking from recollection, having reviewed 0909.

Q You were saying that it was Ginna that had the highest radiological consequences to the best of your recollection?

A. I think that's accurate but I would need to confirm that by looking at 0909.

Q Did you review the radiological consequences of actual steam generator rupture accidents versus the FSAR analyses in preparing this testimony?

A. As my testimony states the "...consequences were all less severe than the FSAR analyses." That is at the bottom of page three in response to 8.

I am drawing that conclusion from 0651 where there were -- where we analyzed three tube ruptures and

agb/agb15

all of the consequences there were less than the FSAR analyses; and also in 0909 where the off-site consequences were less than the FSAR analyses.

Q Okay.

So you did review 0909 to that extent.

A Yes, I did.

Q And by "overall consequences" here, do you principally mean radiological consequences?

A Principally but not all. They are not all. There are other acceptance criteria in Standard Review Plan 15.6.3 that have to be met, not just of off-site consequences.

Q Okay.

And when you say "overall consequences," you are talking about all the consequences that 15.6.3 requires to be met?

A That's correct.

Q Excuse me a minute, I've just got to collect something here.

At the top of page four your testimony states that:

> "...a thorough review of the steam generator tube rupture assumptions, analyses and inherent conservatisms is planned," as part of

the Staff's review; when is that review plan to be initiated, has it already started?

A. It has already started.

Q. When does it start, do you know?

A. Let me give you a little more:

This item was identified in the Generic Program A-3, -4 -5, and it said to the Staff Look very hard at the Standard Review Plan, see if there are any improvements that need to be made there because of the Ginna event and because of the events that were analyzed in 0651.

That assessment started -- that is, the relook at the Standard Review Plan -- that assessment started, I can't say exactly, I would say about a year ago.

Q. Do you have any idea when it is planned to be completed?

A. It is currently scheduled to be done in June of '85, but I am not sure we are going to meet that schedule.

Q. Okay.

Are you participating in this review?

A. Yes, I am.

Q. Okay.

Are you in charge of it?

A. No, I am not. It is a joint effort between our branch and another branch associated with the off-site consequences.

Q. Okay.

agb/agb17

If --

A. May I supplement my answer, please?

Q. Certainly.

A. When I say "relook at the Standard Review Plan," what thi s item really refers to, look at the Standard Review Plan and the extent to which the older plants meet or do not meet the Standard Review Plan assumptions.

The Standard Review Plan now in its present form is a relatively recent document and we know that older plants -- not like Shearon Harris, older operating plants did not have to analyze tube ruptures against the criteria that are in the Standard Review Plan.

But the issues that we are looking at the Standard Review Plan to make sure are there, we have already asked Applicants like Shearon Harris; for example, the isolation time, the overfill, et cetera.

So this -- I don't believe that the Standard Review Plan look-see is going to affect Shearon Harris analyses because we have already asked Shearon Harris questions that we are now asking the Standard Review Plans.

Q. Okay.

Only then if the conclusion of this effort that you are participating in was to go beyond the kind of questions you have already asked the Applicants would you come back and ask them something else, is that right?

A. That's correct.

Q. Would any of the -- Could any of the things that you are looking at here come out within the context of the stipulation; that is, the validity of the analysis that Applicants have to present on the stipulation on Joint 7?

MRS. MOORE: Objection, your Honor, I don't understand the question nor its relevance to the witness' testimony.

JUDGE KELLEY: Maybe you could restate, Mr. Eddleman?

MR. EDDLEMAN: I'll try -- I would have an easier time trying to state what I think the relevance is than trying to restate the question and making it different.

JUDGE KELLEY: Do both.

MR. EDDLEMAN: I think the relevance is that the testimony says that the Applicants' analysis -- this is answer seven -- "...demonstrates that the

> radiological limits of 10 CFR Part 100 are met. However, Applicants are being required to substantiate selected assumptions of that analysis."

And the assumptions involved are ones that do appear to relate to the stipulations from his previous

agb/agb19

answer.

So what he was answering immediately before, as I understood it, was that they had this joint review underway and he didn't anticipate questions to an Applicant like Harris that they hadn't already asked them but there might be some.

And then what I wanted to do was tie that in to the stipulation, either the things come under the stipulation or don't they.

MRS. MOORE: Your Honor, the problem is that this issue is a narrow issue, and it is whether the analysis should contain an analysis of multiple tube ruptures as design basis events; the particular provisions of the stipulation are clearly not in issue here. And the single tube rupture analysis is not -- in itself is not an issue, it is whether a multiple tube rupture analysis should be conducted.

JUDGE KELLEY: Any response to that, Mr. Eddleman?

MR. EDDLEMAN: If the single tube rupture analysis can't meet Part 100 then I'll be doggonned if a multiple tube analysis could do so and it would appear to be a good basis for accepting the validity of this contention if that were so.

MRS. MOORE: But the question as I understand it did not relate -- the witness has clearly stated that the analysis meets Part 100. And Mr. Eddleman accepted a stipulation about certain assumptions in that analysis and the license condition. And that is not a subject for discussion here.

JUDGE KELLEY: But doesn't your stipulation -- I ask for information -- require some substantiation of some of the assumptions or not?

MRS. MOORE: Yes, it imposes a license condition --

JUDGE KELLEY: Okay.

MRS. MOORE: -- on the Applicants to do an analysis which substantiates certain assumptions.

JUDGE KELLEY: Well as an abstract matter you may be right, Mrs. Moore, but it seems to me that this stuff is so interwoven that I am going to overrule the objection. If the witness can answer it, I'll let him do it.

WITNESS MARSH: I think your question was could the results of this assessment go beyond the stipulation.

BY MR. EDDLEMAN:

Q That is a way to say it. If you will answer that.

A (Witness Marsh) Let me try it that way.

It could.

Q It could.

agb/agb21

You won't know until you complete this analysis?

A That is correct.

Q The technical specifications discussed in answer nine, it says that:

"Eddy current testing of the tubes is routinely required every 12 to 24 months."

Is that once every core cycle or --

A That's correct.

Q And if for some reason a cycle goes 36 months, that the plant was operated at a limited output but such that it could stay running for a lot of that time, would the 24-month limit apply?

A (Witness Conrad) Yes, unless there were say, for instance, a leak in excess of the technical specification limit.

Q Now that technical specification limit of 500 gallons a day per steam generator, that is a limit for Harris itself? Is that out of the Harris technical specs?

(Pause.)

A The technical specification has been submitted to us for review, so it is not in its final form, but when I examined the latest draft version or a proposed version it was.

Q The latest proposed version for Harris has a limit of 500 gallons per day per steam generator, is that correct?

A. Right.

Q. Now does that mean, say, that if two generators leak zero and the third one leaks 501 gallons, that they are out of specification or does it mean that the total leakage has to be over 500?

A. If one steam generator has a leak of that size they have to shut down and take corrective action.

Q. Okay.

And all three loops are monitored for leakage?

A. Absolutely.

Q. Now what kind of inspection do they have to do when they shut down under those conditions?

A. The inspection is a technique called eddy current testing.

Q. Does that have to be done for all the tubes in the affected steam generator?

A. Are we talking about the routine technical specification that requires inspection?

A. Well we are talking about this unscheduled inspection here down in the middle -- or down in the end of the first paragraph of answer nine on page four. That's where I am.

Do you have that?

A. You are talking about an unscheduled inspection due to a tube leak exceeding the technical specifications?

Q. Yes, I am.

A. There is an inspection plan criteria, it says due -- of course, you will locate the leaking tube and then they will do an additional 3 percent sample. If they find a certain number of additional tubes that exceed the plugging limit, then the inspection sample increases and it can increase up to 100 percent, that is, all the tubes in the steam generator, if they keep finding enough pluggable defects.

Q. Okay. Is the 3 percent sample based on some confidence limit that if you don't find any in that 3 percent sample you've got a certain confidence level that there aren't any in the whole steam generator?

A. No.

Q. It is not, it just just 3 percent.

How many additional leakages besides the principal one do you have to find in the 3 percent to go on to sample more?

A. It is in the technical specification which I don't have with me --

Q. But you say -- excuse me, I didn't mean to cut you off.

A. I just can't recall what the exact numbers are.

It is designed to increase the sampling if there is any indication of more than the single tube defect that caused the leak.

Q But you say the criterion number is in there that how many leakers you find in your 3 percent sample or in some larger sample you might have to pull are not set on some kind of a confidence limit as to --

A. No, they are not. They're mainly based on our experience with them.

Q It also says there:

"Eddy current indications in excess of 40 percent through wall degradation are are required to be plugged...," does that mean it has to already be in excess of 40 percent?

A. Well 40 percent is a...

Q 40 percent and up is wha that really should say?

A. Yes.

Q Okay.

Then it says "...except for tubes in the preheater section."

Is there a reason why a tube in the preheater section would be allowed to leak or rupture?

A. It is a tighter requirement. I don't recall exactly what it is, but it has to be even tighter than the

agb/agb25

regular 40 percent because that would be controlling.

Q So it's got to be less than 40 percent?

A Right.

Q Is that also in the tech specs?

A Yes, I believe it is.

Q Okay.

A Yes, it would have to be.

Q Okay.

Now it then says:

"In this manner, the integrity of the steam generator tubes is systematically monitored to uncover any defect or degradation before tube degradation becomes serious."

Are either of you gentlemen familiar with the Ginna tech specs that were in effect before their steam generator tube rupture?

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A (Witness Marsh) I am not.

A (Witness Conrad) Not in any detail.

Q. Would an operating plant in that timeframe, say, early 1982, have been required to have a program like this? This is, that if they have a leak they have to do inservice inspection and it would have had --

Well, let me ask you this. Are either of you familiar with the criteria for -- you know, sample sizes or percent leakers that requires a larger sample to be checked -- have changed since the Ginna accident?

A. (Witness Marsh) I don't believe they have changed but as one of the recommendations coming from the Ginna tube rupture event and which the commission is still considering, is the tube inspection intervals and size. I don't recall the exact status of this recommendation, but I know it's under consideration by the commission.

Q. If the results of that review come out before Harris went commercial -- assuming it might -- would they apply to it, or could you tell?

A. To the best of my knowledge, what the commission is -- let's see, how to answer. Let me ask you to rephrase the question or ask the question again to make sure I give you an accurate answer.

Q. All right. The commission has under review the requirements for sample sizes and leak detection for steam generator tubes, since the Ginna accident, correct?

A. That and other recommendations; that's true.

Q. Okay. So, a number of recommendations coming out of that accident, right?

A. That's right.

Q. My question is, if the commission completed its review on any one or group of these recommendations and put some additional requirements into effect before Harris went commercial, would those limits apply to Harris?

A. I'm sure they would. I'm reasonably familiar with what is going on in 0884, and I don't think there's anything there that would preclude the recommendations applying to Harris.

Q. Further in this answer it states, "The limits on allowable primary to secondary leakage are designed to assure that tube leaking at a rate equal to or less than the limit, will retain adequate integrity against rupture."

A 500 gallon per day leak is something on the order of a third of a gallon per minute; is that correct?

A. That sounds right; pretty close.

A. (Witness Conrad) Pretty close.

Q. Now what size or nature of defect would be necessary at, say, a thousand pounds per square inch or normal operating pressure differential to get a leak of that magnitude.

MR. MARSH: Excuse me.

(Witnesses conferring.)

A. (Witness Conrad) I don't think we have the exact figures on the source of that break, but the idea is that you can relate a leak rate to a crack size and then you can calculate if that crack size is greater or smaller than a so-called critical crack size for it that would lead to the first critical crack size if the size of the crack above which they will go unstable, go from, say,the leak to a break. So the idea is that the intent is the leak rate limits are set such that we will have a leak before a break.

Q. Well, the four ruptures that have actually taken place in American Westinghouse nuclear plants, did those, in fact, leak before break?

A. No,they didn't.

A. (Witness Marsh) I thought there was some leakage in one of the events?

A. (Witness Conrad) Some leakage below the tech spec limit, so it was smaller than the technical specification limit up to the time when it increased way over the technical specification limit?

Q. And that was in one of these instances, you say?

A. (Witness Marsh) I believe so. I believe it was the Point Beach event, but I'm not sure.

Q. You say in the last sentence on that page,"in such cases the plant is shut down in an orderly manner for tube plugging." This is, when serious flaws have gone undetected.

Would you say that Ginna was shut down in an orderly manner in that 1982 accident?

A. No, we would not. But I think the intent of that statement is that where flaws, where you haven't found flaws because of the eddy current testing or because of your inspection program, the normal consequence of a detection is for there to be a small leak that is, in fact, what normally happens. In the Ginna event there was an external loose part which caused rapid deterioration of the tube. And the tube burst.

So no, I would not say that the Ginna tube rupture shutdown was an orderly shutdown. But the intent of the statement is that most leaks, when they do occur, are small and are manageable. And as we said, the thrust of all of these arguments is not to be that there will never be a tube rupture at a plant. There very well may be a tube rupture at a plant. But what we're stating is that when it does occur, that if a tube does leak, it's normally a small leak and the plant can be shut down in an orderly manner. If the tube rupture does occur, past experience has shown us that in most cases the leak that's going to be less than the design basis of that. And in all those cases the consequences are less than the safety analyses.

Q. Let me ask you a followup on that. You're not saying either, are you, that there can't be steam generator ruptures with consequences beyond those of the safety analysis, are you?

A. No, I'm not saying that.

Q. Now, on page 5 in your answer 10, you gentlemen reference, and I quote: "Various calculations performed for another Westinghouse PWR." Now, do you give any reference in the testimony as what document contains those calculations, or which PWR that is, any way to identify the document where you define those calculations?

A. No, it's not in the testimony.

Q. Okay. Why not?

A. I don't have any reason why it wasn't there, to tell you the truth. It was analyses that were done for Zion, a four-loop plant. And it's omission here was not intended to mean anything.

Q. Okay. If you were writing a technical or scientific paper on this, you would normally give a reference when you refer to calculations supporting your position, wouldn't you?

A. I wrote a technical paper recently, and I did not refer to a particular plant.

Q. But would you give the source of the documentation?

A. I did say in this other paper, "Analyses conducted by Los Alamos National Lab."

Q. But, I guess what I'm getting at is, well, as a reviewer, how would you be able to analyze a statement like this, saying"there are some calculations had been performed for some plant that indicate the following." How would you check that?

A. You would need to know the reference, I agree.

Q. Okay. The conclusions that are stated down there in the next sentence of answer 10, still in the first to answer 10, it talks about primary coolant national regulation et cetera. Are those conclusions from the same Zion study that you were talking about?

A. I lost track of where you were, I'm sorry. What sentence are you on?

Q. Okay. I had started with the first sentence of answer 10 and asked about the reference and you said it was for the Zion plant, as I understood it; is that right?

A. That's right.

Q. Okay. So then I was asking you about the conclusions in the next sentence, whether they were derived from that study?

A. That's right, they were. But not only that study, I assume you're referring to the sentence that starts, "Primary coolant, natural circulation--"

Q. Yes.

A. "-- steam generator, auxiliary feedwater --" The calculations that I'm referring to in this testimony are the

Zion calcul ·tions. But my judgment comes not only from these Zion calculations, we have seen many multiple tube rupture analyses that have been done for the other two PWR NSSS's under a variety of accident scenarios.

Q Now, the other two PWR NSSS's, is that the combustion engineering in the Babcock and Wilcox design?

A. That's right.

Q Okay. Is Zion the only multiple rupture analysis for a Westinghouse design, that you know of?

A. I'm not sure. There may have been another done for a tubal plant, but that's just recall, I can't say exaclty. I am familiar with the Zion analyses, though.

Q Then you also say that -- the end of that paragraph -- "calculations performed by Westinghouse in support of a new emergency operating guidelines have shown similar results." You don't give any reference for that, either, as to the paper, do you?

A. No, I do not. Again,here, it was not meant to withhold any information at all. The information is contained in the New Emergency Response Guidelines, Revision One, the background information for the E-3 series.

Q Could you give me that reference one more time?

A. Yes. Revision One to the Westinghouse Emergency Response Guidelines, the HP version, and the particular guideline are the E-3 series. E-3 refers to steam generator tube rupture guidelines.

JUDGE KELLEY: Excuse me, Mr. Eddleman. We are around the time that we normally take a break of some sort. I don't mean to rush you, but could you give me an indication of where you are on cross with this panel?

MR. EDDLEMAN: I have probably got another 20 or 30 minutes.

JUDGE KELLEY: That is what I was sort of wondering. Just following your sequence, I thought that might be about it.

I was wondering whether we might finish, that would be pretty hard to do.

Were you gentlemen counting on goint home tonight?

WITNESS MARSH: Trying but not counting.

JUDGE KELLEY: Trying but not counting.

We were thinking before we would probably want to quit around quarter to 6:00 or so, I don't think we can go after 6:00 in any event because we are being evicted from here this evening, they are going to take our sound away and do something else with this room.

Well let's take a short break. It's about seven after, let's resume at quarter after and we might finish the cross, in any event. We'll see how it goes.

(Recess.)

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JUDGE KELLEY: Mr. Eddleman, do you want to resume?

BY MR. EDDLEMAN:

Q. Gentlemen, the second paragraph of Answer 10 on page 5 says the Staff compared the parameters most important in tube rupture accident scenarios.

Did either of you gentlemen do that comparison?

A. (Witness Marsh) I did.

Q. And it says "for example, power, volumes, temperature and safety injection system characteristics." Were those all the ones that you checked?

A. No, that's not all. But those are, in my opinion, the most important characteristics. There are other characteristics, too.

Q. In preparing this testimony did you actually go down a list and compare them all, and make notes?

A. Yes, I did.

Q. And you didn't include any of those comparisons in the testimony, just the conclusion; right?

A. If you mean did I include the actual power of Zion and the power of Shearon Harris in the testimony, no, I didn't.

Q. Nothing on the characteristics of the injection systems or--

A. I did not include those characteristics in the

WRBwb2

testimony, no.

Q. All right.

Again, you'd agree as a reviewer that it's kind of hard to look at a statement like that and know what the specifics are and evaluate it, wouldn't you?

A. I agree that it would have been easier to evaluate this knowing the plant, so you could have seen the characteristics for yourself.

Q. Now, given that this analysis was done for Zion, could such an analysis have been done for Shearon Harris?

A. It certainly could have.

I think what we're saying here, though, is that in our opinion it need not be done for Shearon Harris based on the entirety of the testimony. The analysis that we did for Zion -- and it was done by Westinghouse for the emergency response guidelines -- showed that the existing safety systems do enable the operators to manage the event adequately.

Q. Has there been such an event that operators have been faced with in real life yet?

A. If you mean a multiple tube rupture, not to my knowledge.

Q. Well, you discuss on pages 5 and 6 in the paragraph that begins there at the bottom of page 5 "a variety of beyond tube rupture accidents." And then you mention tube rupture accidents combined with other accidents, and so on.

WRBwb3

Have any of those things actually happened that an operator had to deal with yet?

A. During the Ginna event there were some things that happened that the Staff judged the procedures that were in place at the time were not adequate. I don't want to say that they were beyond the design basis, because the design basis -- that is, the analysis that was in the Safety Analysis -- bounded that situation.

But there were some facets of the Ginna event which were not in the procedures, and they have now been factored in.

Q. So based on this accident that happened improvements were made, and now you're saying those improvements should be adequate to handle anything that comes along? Is that what you're saying?

A. Well, again, I'm very hesitant to say anything that comes along. I do want to say that the new procedure guidlines are significantly better than the old procedures which were in place at all the operating PWRs. The new procedure guidelines are not so much symptom-- Excuse me; are not so much actual event mitigation, rather they are symptom oriented procedures; they tell the operator what things to look for, rather than trying to identify the event per se. And they tell the operator as he reads through the procedures to watch out for certain key indications that tell him that

WRBwb4

there's something else going on other than where he thinks he is. For example, in the tube rupture procedure it tells the operator to watch out for containment indications, for an excessively low secondary pressure. That would tell him that there's something else going on other than just a simple tube rupture accident.

Q. So what you're saying is that the difference in these new proceduresis, rather than just finding an event and following through a single scenario for that event, the operator is now warned to watch out for other things; is that right?

A. That's true; he's not only told to watch out for other things, he's also given some critical key parameters in the plant that he must always monitor.

Q. Now, will these procedures be required for Harris, to your knowledge?

A. To my knowledge, as I say in the testimony, Shearon Harris has committed to using the newest emergency response guidelines. And those are the procedures that I'm referring to.

Q. When you say before there that the Ginna accident FSAR analysis bounded the event, you meant bounded the consequences, didn't you?

A. That's correct.

Q. Okay.

WRBwb5

And wouldn't it be likewise true that problems could occur that even aren't taken care of under the procedures that have been improved that you're talking about?

A. Again, you're saying could they occur. I can't disagree: anything can occur. And my comment to that, as I stated previously, was that the new procedures that are going to be used at Shearon Harris are symptom-oriented procedures, they should cover significantly more additional events than were originally postulated.

Q. Well--

A. I can't say that they're going to cover all situations. That implies that we know everything that's going to occur, and we don't.

Q. When an accident like Ginna happens, which has some aspects that weren't covered before, that's how in fact you take care of things that don't seem to be sufficiently conservative in analyses like this and procedures like this, isn't it?

A. I'm sorry; would you say that again? I didn't understand.

Q. Let me rephrase that.

There are some actual accidents like Ginna that show up some inadequacies of procedures, aren't there?

A. Yes.

Q. So there's really two ways of getting

WRBwb6

conservatisms in an analysis of something like steam generator tube ruptures. One is to have the conservatism in the pre-existing analysis, and the other is to have an accident, or accidents, that points up where you need to make improvements. Would you agree?

MRS. MOORE: Objection, your Honor. That question is irrelevant to his direct testimony.

JUDGE KELLEY: Any comment, Mr. Eddleman?

MR. EDDLEMAN: Well, he says they're ensuring various things, and I don't think they really are. That's what I'm trying to get at.

JUDGE KELLEY: Would you restate the question, please?

MR. EDDLEMAN: Yes, sir.

BY MR. EDDLEMAN:

Q. Isn't it true that a principal way of finding out that existing procedures or analyses are inadequate is by having an accident that is worse, or has consequences not contemplated in those procedures occur?

JUDGE KELLEY: I will allow the question.

Go ahead and answer the question.

WITNESS MARSH: To answer that it is not just one particular facet of an accident which may not have been addressed in the procedures themselves, as was the case during the Ginna event, there were things that happened during the

WRBwb7

Ginna event which had not been adequately addressed in the procedures. We found that out.

But we did confirm for ourselves that the analysis that we have still bounds, even in those situations where the procedures were not adequate. It gives us confidence in the conservative nature of the design basis events.

BY MR. EDDLEMAN:

Q. It bounded that event?

A. (Witness Marsh) That's true. And it bounded all of the tube rupture events.

Q. All right.

I think you have already said there that the analysis here does not rule out a more severe accident.

MRS. MOORE: Objection, your Honor. Asked and answered.

MR. EDDLEMAN: I'll drop it.

JUDGE KELLEY: All right.

BY MR. EDDLEMAN:

Q. Let me ask you about your Answer 11 here on page 6. The last sentence on that page is a pretty long one. It says "The Staff believes the combination of preventative measures," and that goes through a listing of preventive measures, "further confirm that the applicants need not include multiple tube failure accidents in the plant's design basis."

End #21

Q Is that the logical equivalent of saying they could handle it even though it happens so they didn't have to analyze it?

A No, that is saying to me that the Applicant nor any PWR at this point need not consider this event within its design basis for two reasons.

First, there are a number of measures that we believe are going to prevent it from happening. However, should it happen, and we believe it is not likely, analyses have been conducted to show that they could handle it.

Now if we conducted a thermohydraulic calculation and it showed that this plant could not handle it, if it showed that some of the limits would not be acceptable, we would have to reassess very carefully whether this should be assumed or not.

If you were trying to consider whether to postulate a loss-of-coolant accident as a design basis event without any ECC systems you could make a similar argument as the first sentence. We believe that the design and the inspection of the reactor cooling system is such that we don't think it is going to happen.

But you could not make the next argument without ECC systems that the analysis requires, so it is the combination of both of those aspects, that is, we don't think it is going to happen, and even if it did happen we can handle it, that leads us to conclude that you need not postulate it.

Q And therefore need not analyze it?

A Need not analyze it in a design basis space, in the design basis space. That doesn't mean that you shouldn't have procedures to deal with it should this low likelihood event occur.

Q All right.

Does that mean then in fact some analysis has to be done to make sure that the accident could be dealt with?

A I think that Westinghouse has conducted that analysis and confirmed to the Staff's satisfaction that those procedures, the emergency response guidelines, are sufficient to handle multiple accident scenarios.

Q Meaning multiple tube ruptures, or other accidents as discussed on pages 5 and 6?

A That's right.

Q Okay.

MR. EDDLEMAN: No more questions.

JUDGE KELLEY: Thank you.

Applicants?

MR. O'NEILL: No questions.

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EXAMINATION BY THE BOARD

BY JUDGE CARPENTER:

Q I would a little help, sir, on your response to

Question 8 on page 3 of your testimony.

A (Witness Marsh) Yes, sir.

Q Looking at the last paragraph on that page, there are two sentences which I think logically flow from one to the other, and I was curious to know, for the four tube rupture events that have occurred, which assumptions -- and I'm going from the second sentence now back to the first sentence -- which of the assumptions in the accident analysis was actually exceeded.

A Sir, one of the assumptions that was exceeded, or not met at least, was the 30 minutes isolation time assumption. And I just add to that though that the analysis that Westinghouse conducts for an FSAR analysis is that a tube rupture occurs at time zero and the leak progresses for 30 minutes unabated. That means the operator takes no actions in the 30-minute time interval.

The steam generator pressure rises up to its safety valve setpoint and leakage out the safety valve occurs in that interval. At the end of 30 minutes, the analysis is stopped by Westinghouse. What that means is-- And they have assumed that within that 30-minute interval, the operator can take the necessary actions to insure that the leakage is stopped in that 30 minutes.

Q Was the Ginna incident what you are specifically referring to here?

A Not only Ginna, all the other-- Virtually all the other events showed that 30 minutes was tough to achieve although if there is a smaller leak rate there is less pressure on the operator to depressurize within 30 minutes as assumed in the safety analysis.

So it's a balancing effect. We did not know and still don't know the nature of the conservatisms in that 30-minute assumption because if you allow operator credit to that first 30 minutes, that is going to make the analysis more valid but it is also going to reduce the leak rate because the system pressure will be dropped by the operator in that timeframe.

Q Thank you. That makes it clear to me.

BY JUDGE KELLEY:

Q You may have already spoken to this, at least indirectly if not directly, but I just wanted to be clear in my own mind.

Are you familiar, both you gentlemen, with the testimony of the Applicants' witness, Mr. Hitchler?

A (Witness Marsh) Yes, sir.

Q And are you familiar with the calculations that he went through determining his predictive frequency of tube failure, and the conclusions he drew from that?

Do you agree with those calculations?

A Sir, I agree with the overall conclusion that he made; that is, that tube ruptures need not be postulated because of the overall frequency and risk numbers. I make that conclusion because I have compared that to the 0844 assessment, but I am unfamiliar with the statistical techniques like these, and with the ones that were used in 0844 to say that I agree or disagree with how he came to those conclusions.

Q So you were taking different streets to the same square, so to speak?

A That's right, sir. We did not rely in any way on any probabilistic assessments in coming to our conclusions.

Q That is what I thought. Okay.

Mr. Conrad, do you have any view on-- Do you agree or disagree with the calculations?

A (Witness Conrad) I have the same problem. That is quite outside of my field, so I can't judge in detail the procedure. But the conclusions are the same as my own.

Q Yes, I understood. I thought the conclusions were the same and I just wondered whether you would provide us or sought independent verification or independent disagreement with the way he got to his conclusions. And the answer I think is No. Right?

A That's right, sir.

Q Thank you.

JUDGE KELLEY: Anything more based on that, WRB/eb6

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Mr. Eddleman?

FURTHER CROSS-EXAMINATION

BY MR. EDDLEMAN:

Q You just said in response to Judge Kelley I believe that your analysis for the Staff is not based in any way on probability calculations.

A (Witness Marsh) I hope I said probabilistic risk assessment.

Q Okay. It is not based on any kind of PRA.

Do the Westinghouse calculations for Zion that you reference in your answer 10 have any probabilistic components in them?

A No, sir, they do not. The Westinghouse calculations that I refer to in 10 are purely thermohydraulic calculations.

MR. EDDLEMAN: That is all I have. Thank you very much.

JUDGE KELLEY: Okay, Mrs. Moore. Is there redirect?

MRS. MOORE: No questions, your Honor.

JUDGE KELLEY: Okay.

Well, gentlemen, that completes our process then. We appreciate it very much. You are excused.

(Witness panel excused.)

JUDGE KELLEY: Maybe a word or two about tomorrow from us.

Mr. Runkle, do you have a comment or a question?

MR. RUNKLE: Yes, sir.

Per our discussion this morning I have copies of the letters and stuff on the FOIA request, and I will distribute those.

JUDGE KELLEY: Fine. We will take a look at them and maybe we can discuss it some more in the next day or two, and make a little progress on what to do about that.

I think everyone is aware -- I will simply repeat -- that this room is not available to us tomorrow, and we regret having to move back and forth so much but it is going to be necessary tomorrow for us to convene in the Bankruptcy Court in the Old Post Office Building on Fayetteville Street Mall, I believe it is called.

I think all the participants were there last summer and know where we are to be. So we will plan on convening there tomorrow morning at nine o'clock, and then Thursday and Friday this week we will be back here, and I believe four days starting Tuesday next week. But those are our immediate plans in that regard.

You will have to-- This is the hardest part. If you bring large boxes of paper I'm afraid you're going to have to take them away with you this evening, but hopefully we can at least minimize that as time goes on.

Any questions or points or anything that needs to be said beyond that?

MR. RUNKLE: What is the starting time tomorrow?

JUDGE KELLEY: Nine.

MR. RUNKLE: Thank you.

JUDGE KELLEY: And with that then we will adjourn for the evening and see you tomorrow morning.

Thank you.

(Whereupon, at 5:37 p.m., the hearing in the above-entitled matter was recessed to reconvene at 9:00 a.m. the following day in the Bankruptcy Court, Old Post Office Building, Fayetteville Street Mall, Raleigh, North Carolina.)

CERTIFICATE OF OFFICIAL REPORTER

This is to certify that the attached proceedings before the UNITED STATES NUCLEAR REGULATORY COMMISSION in the matter of:

NAME OF PROCEEDING: Shearon Harris Nuclear Power Plant

DOCKET NO.: 50-400-OL & 50-401-OL

PLACE: Apex, North Carolina

DATE: Tuesday, October 16, 1984

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission.

(Sigt) William R. Bloom Anne G. Bloom

(TYPED) William R. Bloom & Anne G. Bloom

Official Reporter

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