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NUCLEAR REGULATORY COMMISSION

BRIEFING ON PRESSURIZED THERMAL SHOCK

PUBLIC MEETING

Nuclear Regulatory Commission
Room 1130
1717 H Street, N. W.
Washington, D. C.

Wednesday, December 1, 1982

The Commission convened pursuant to notice, at 2:05 p.m.

COMMISSIONERS PRESENT:

NUNZIO PALLADINO, Chairman of the Commission
VICTORY GILINSKY, Commissioner
THOMAS ROBERTS, Commissioner
JAMES ASSELSTINE, Commissioner

STAFF AND PRESENTERS SEATED AT COMMISSION TABLE:

S. CHILK
M. MALSCH
J. ZERBE
H. DENTON
S. HANAUER
R. WOODS
F. SCHROEDER

AUDIENCE SPEAKERS:

T. MURLEY

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P R O C E E D I N G S

CHAIRMAN PALLADINO: Good afternoon, ladies and gentlemen.

The purpose of this afternoon's meeting is to have the staff brief the Commissioners on issue of pressurized thermal shock. We have had a number of discussions with the staff on this subject previously, but they have generally concerned status reports and plans for future studies.

Recently, however, the staff has completed a report from which it has based a set of recommendations now before the Commissioners. I understand that the staff is prepared to discuss the details of the report and provide answer to questions on the recommendations.

I have noted that the package of slides to be used today is rather lengthy, and I am fearful that we will not have time to look at each and everyone of them, and still allow time for questions.

COMMISSIONER GILINSKY: I was fearful that we would.

CHAIRMAN PALLADINO: I want to make sure that we provide sufficient time at the end of the meeting to provide time for Commissioner questions, and to discuss the recommendations that are before us.

We do not plan to vote today, but we may vote at the next meeting on this subject, which is scheduled for the week of December 6.

Do any of the other Commissioners have opening comments?

COMMISSIONER ASSELSTINE: No.

COMMISSIONER GILINSKY: I don't have any opening comments, but I did want to --

You answered the question I was going to ask, which is, are we going to vote today, because I am going to have to leave before the end of this meeting to catch a plane to the West Coast. I guess that resolves that question.

I did have one question of the staff before they began, and that was, whose views does this paper represent?

It is signed by Mr. Dircks, and at the bottom it says, Steve Hanauer with his phone number. Is this an NRR view?

MR. DENTON: I think it is fair to say that it is an EDO staff view. It has been reviewed by the ACRS, and they have issued their report that agrees with it. It has been reviewed by the CRGR. I am sure Mr. Dircks concurs in this paper. NRR has proposed it. Steve Hanauer is the principal technical expert in this area.

COMMISSIONER GILINSKY: But it does represent

NRR's views.

MR. DENTON: It is NRR's views, and it also represent the EO's and his other offices' views also.

COMMISSIONER GILINSKY: Thank you.

CHAIRMAN PALLADINO: Any other questions?

COMMISSIONER GILINSKY: No.

CHAIRMAN PALLADINO: Then I will turn the meeting over to Mr. Denton.

MR. DENTON: Thank you, Mr. Chairman.

The main presentation will be made by Steve Hanauer. I want to mention that this is his swan song in appearing before the Commission. He is going on to greener pastures in the next few days, he hopes.

COMMISSIONER GILINSKY: He hopes it is greener.

MR. DENTON: He will be assisted by Roy Woods, who has been the Project Manager for this project over the last couple of years, and he will also be assisted by Frank Schroeder, over on my right, who is the Assistant Director for Generic Projects under Steve.

We have had an awful lot of activity in this area over the last couple of years. It has occupied time of many of the technical specialists. We have a number of peer reviews. We have had the Pacific Northwest Laboratory as a consultant to advise us all along the way. We obtained the advice of several consultants in this area, including consultants such as Spence Bush, a former ACRS member, Bob Budnitz, whom you know. We have also gotten advice from Oakridge National Lab. We have consulted with George Irwin, who is sort of the father of facture mechanics in the U.S.

We think that the time is ripe for a decision regarding thermal shock, and it is our view that adoption of the action we recommend today will provide adequate public protection against risk from this type of event.

The action is of three types. It recommend issuance of regulations to deal with those plants which are a long way from tripping our criteria; it recommends the issuance of 50-55(f) letters to a group of plants who need to do something between now and the end of their life to assure that they stay within the guidelines that we have proposed; and it recommends the issuance of an order for one plant, Robinson, which appears to be unable to reach the end of life without rather drastic changes in their mode of operation.

With that introduction, let me ask Steve to walk through these slides and answer your questions.

MR. HANAUER: Thank you, Harold.

Mr. Chairman and gentlemen, the package of handouts which I gave you should not be as awesome as it first appears. Only about the first half of it is intended for discussion, and the last half is backup material in case questions are asked. Many of them are unsuitable for projection, so I plan to work just from the package of handouts.

You have from us a paper, SECY-82-465, with a number of enclosures. Separate from that, you have received from us a very thick report which purports to be enclosure A to that SECY paper. More recently, you received from us a package of errata on those, in which certain typos and other things have been fixed.

COMMISSIONER GILINSKY: Is that report now a public document?

MR. HANAUER: Not until today, but it is now on the back table, we will send it to the Public Document Room immediately.

COMMISSIONER GILINSKY: Thank you.

MR. HANAUER: The draft of that report was discussed with the ACRS and was sent to the Public Document Room in September.

The pressurized thermal shock issue involves over-cooling transients, reactor vessel properties, and the fracture mechanics which establish whether the vessel will, in fact, fail under the stresses which are imposed by these over-cooling transients in the presence of the flaws with the various vessel properties. Therefore, it is necessary to discuss all these areas in order to get to the end of this subject.

What we have done is --

COMMISSIONER ROBERTS: Excuse me, I don't mean to nitpick, but I thought you said, "in the presence of flaws in the vessel wall."

MR. HANAUER: Yes, sir.

COMMISSIONER ROBERTS: Is that an assumption? Is that known?

MR. HANAUER: It is all of those things, sir. In any individual vessel, there is an inspection history which gives you an insight as to the presence or absence of flaws in that vessel.

In a generic discussion, in our deterministic work, we assume that there is a flaw, which is a big conservatism, and in our probabilistic work, we have a probability distribution of the presence or absence of flaws of various sizes in order to be more realistic.

We believe that a flaw or a discontinuity of some kind is a necessary part of a pressurized thermal shock occurrence, and that a flaw-less vessel will not experience failure.

COMMISSIONER ROBERTS: But you assume there are flaws?

MR. HANAUER: Yes, sir.

COMMISSIONER ROBERTS: Okay.

COMMISSIONER GILINSKY: They are human.

MR. HANAUER: Page 2 in the handout gives an overview of how we treat overcooling transients. The X axis is temperature and lower temperatures are more severe, so the left-hand side of the drawing, as you go toward the left, you get to more severe things, with colder and colder transients which produce less and less favorable vessel characteristics.

The Y axis is probability. Sometimes we know the probability and sometimes we don't, but it is always there. The solid curve is meant to give some idea of the whole range of the probability of things that could happen. The curve is not well delineated, although I will come back to an estimate of this curve later.

Up in the right-hand corner is another probability curve which is obtained by analyzing the over-cooling accidents which have actually occurred. There is a limit to that. We have had no accidents more severe than the ones shown on that curve.

CHAIRMAN PALLADINO: The probability is probability of what; in-vessel failure?

MR. HANAUER: It could be any of those things since this curve is only schematic. It could be vessel failure, or only probability of getting that kind of a transient. Later on I will show you both, transient probability curves and vessel failure probability curves.

COMMISSIONER GILINSKY: What are the lowest temperatures we have had to work with, or that we have experienced?

MR. HANAUER: The lowest temperature we have experienced is on the order of 200 and a few degrees.

COMMISSIONER GILINSKY: Where was this?

MR. HANAUER: The most severe one was the TMI-2 accident. It turned out, besides all its other stresses, to have been the worst over-cooling transient we have ever had.

COMMISSIONER GILINSKY: An interesting distinction.

MR. HANAUER: I have shown not only the experience curve, but also a curve based on probabilistic evaluation and in an effort to be realistic I have shown that they agree only approximately, which is in fact the case.

COMMISSIONER GILINSKY: I realize that this is schematic, but when you put down an outlier, that represents the sort of thing that we have just talked about at TMI?

MR. HANAUER: No, sir.

COMMISSIONER GILINSKY: Is that the experience?

MR. HANAUER: TMI is one of the axes on the experience curve.

COMMISSIONER GILINSKY: So it would be the end of the experience curve.

MR. HANAUER: Yes.

The outliers are the sequences that we dream up that appear to us to be severe. We have had about one of these a month in the past six months. They have a tendency to look very bad the first three days you hear about them. Then they get analyzed in much more detail.

COMMISSIONER GILINSKY: This is a calculational phenomenon --

MR. HANAUER: Yes, sir.

COMMISSIONER GILINSKY: -- when you say that we have had one every few months?

MR. HANAUER: Yes.

Most of them disappear into the curve. Some of them don't, and the ones that don't disappear into the curve, the curve has to be moved to accommodate them.

COMMISSIONER GILINSKY: What sort of temperatures are you talking about there?

MR. HANAUER: We had one outlier, one day that I remember very well, that went down to 60 degrees and was thought to have a probability in the range of 10 to the minus 4 per reactor year.

CHAIRMAN PALLADINO: Which way are these -- This curve is telling that if I have a high temperature, then I have a high probability of something?

MR. HANAUER: Yes, sir. High temperatures are good for you. It is cold temperatures that give you trouble.

CHAIRMAN PALLADINO: That is why I needed to know what this is a probability of.

MR. HANAUER: This is the probability of getting a transient worse than some temperature, which means colder than some temperature. So that as the temperature gets lower and lower, the chance of you getting a transient is lower and lower.

CHAIRMAN PALLADINO: This is the dividing line.

MR. HANAUER: Yes, sir.

CHAIRMAN PALLADINO: Okay.

COMMISSIONER GILINSKY: You can think of it as the relative probability also.

MR. DENTON: The more specific ones may be more useful. This was just to illustrate the ones tat connect.

MR. HANAUER: Page 3 gives a particular transient, the one that occurred H.B. Robinson when a secondary line developed a large leak. The two small diagrams are the pressure and the temperature that were actually measured as a function of time.

As you can see, the pressure went down and then back up again, and the temperature went down by about 200 degrees. So this was an over-cooling transient of some considerable concern, although in that plant it turned out not to do any harm.

On the left-hand side of the page, the same transient is plotted in a different way. You have on the X axis the temperature and on the Y axis the pressure, and so a point moves along as the transient developed and draws this funny looking curve.

CHAIRMAN PALLADINO: Up at the top?

MR. HANAUER: Yes.

I have also drawn, on the right-hand side, the saturation curve of boiling water. So if you get into the hash-marks on the right-hand side, you are in the realm of potential under-cooling of the core. On the left-hand side, hashed, is a reactor vessel, this is an over-cooling limit which is chosen for a vessel just at our screening criterion. Not the real vessel as it was that day, but a fictious vessel that had embrittled just to the proposed screening criterion.

The point here is that you have the space in-between where everything is okay. You are never under-cooled nor over-cooled. As you can see, this particular transient started -- If you look at the upper-central curve, it started on the right-hand side and moved toward the left, but it stayed entirely in the acceptable region.

COMMISSIONER GILINSKY: What is the significance of the dashed-line?

MR. HANAUER: The dashed-line is the limit imposed by the technical specifications for normal heat-ups and cool-downs. You are not allowed in the section to the left of the dashed-line for normal heat-ups.

Where you have many of them, you are in normal conditions rather than accident conditions. So that the normal operation of the reactor should be in the more restricted curve region.

The next two pages, which we don't have to dwell on, are two more transients. I want to linger on them just long enough to look at their jagged nature.

The pressure goes up, the pressure goes down. On page 5, the temperature goes down and the temperature goes back up again. These are what actually happened in these particular events, and they are caused by operational things -- valves closed, valves opened, operators did this, operators did that.

So the operating point moves around and the pressures go up and down, and the temperatures go down and up.

COMMISSIONER GILINSKY: Let me ask you, what is the line with the short dashes beyond saturation; is that the --

MR. HANAUER: That is 50 degree sub-cooling, which is a commonly proposed limit for orderly transients that don't -- I am sorry, that is the solid one. The dotted one is saturation.

COMMISSIONER GILINSKY: The actual saturation?

MR. HANAUER: That is your actual saturation.

COMMISSIONER GILINSKY: Okay.

MR. HANAUER: On page 6 is a stylized transient. In the present state of our calculational technique, I will try to indicate where, we sometimes have to use this stylized transient. It is an exponential temperature decay and a constant pressure.

So it has none of the ups and downs that are encountered in real life in some of these transients. So it is an over-simplification which we use in the present state of our calculational ability. Sometimes we use it, and sometimes we don't, I will try to tell you when.

Page 7 gives the result of fitting that stylized transient to the eight transients that have actually occurred. What is plotted here is this temperature that it goes down to, and on the left-hand side a probability, a frequency.

So this is a probability curve for transients, and it is the probability of getting a temperature lower than that amount. So the probability of getting a temperature less than 300 degrees for this class of reactors is about three times 10 to the minus 2 per reactor year. So once every 30 reactor years, we expect to get a temperature lower than 300 degrees, and there are about 50 of these reactors, so we expect to see somewhat more than one transient a year like this.

COMMISSIONER GILINSKY: Let's see, this lumps together experience from the different reactors, so some have experienced more transients and others less.

MR. HANAUER: This curve is for the PWRs in the United States up till now. Now, not all PWRs in the United States are as they were when they had these transients. For example, there was a transient at Rancho Seco, which is one of the transients plotted here. Since that time, Rancho Seco and some other reactors have been fixed, so that initiating event is less likely.

COMMISSIONER GILINSKY: This is the estimate based on what?

MR. HANAUER: No, there is no fudge factor in here. This is what has happened.

COMMISSIONER GILINSKY: Since when?

CHAIRMAN PALLADINO: Based on the experience.

MR. HANAUER: Based on the eight over-cooling transients worse than 350 that have actually been experienced in the United States.

COMMISSIONER GILINSKY: Since when?

MR. HANAUER: Since the beginning of the commercial power program.

COMMISSIONER GILINSKY: Aren't those more heavily concentrated in the B&W reactors?

MR. HANAUER: Yes, sir, they are, and there is a later viewgraph with a statistical analysis of that, a later page.

COMMISSIONER GILINSKY: You may come to this later, if you want to put it off. On an earlier curve where you draw the line on the over-cooling side, what sort of margin of safety is there in that line? We have already passed the line for normal operation, and you are now talking about the line beyond which you don't want to get even in an accident condition.

MR. HANAUER: There is some considerable margin in that, it comes from the very next page, which is page 8. Page 8 is the result of deterministic fracture mechanics calculations.

On this page, we assume that there is a flaw, and we assume that the flaw is as big as it needs to be to crack the vessel. So this is a very conservative page. Later on, we do it more consistent --

CHAIRMAN PALLADINO: How big must the crack be, for example?

MR. HANAUER: For the eight -- Actually, we have analyzed this for the eight over-cooling transients we actually had, and the critical flaw size is about an inch deep.

COMMISSIONER ASSELSTINE: Do you mean big enough to propagate?

MR. HANAUER: Yes, sir.

CHAIRMAN PALLADINO: An inch deep, but what is the length?

MR. HANAUER: The length is very long in this model. Another conservatism, although less conservative than might otherwise be.

CHAIRMAN PALLADINO: When you say, very long --

MR. HANAUER: Very long. The model says, infinitely long. In fact, it can be -- We have some experimental data. The initial is probably not long, but the flaws that propagates, the experimental data is, gets quite long.

COMMISSIONER ROBERTS: Could the flaw that you assume, be detected by ultrasonic testing?

MR. HANAUER: Yes, we think so. Perhaps, in a borderline way, by the code required ultrasonic testing, but there are better ultrasonic testing methods available today, they are being used, and we think there is a pretty high probability that they would be detected.

COMMISSIONER ROBERTS: Would the ten-year in-service inspection show such a possible flaw?

MR. HANAUER: That depends on how it was done. If it were done only to code requirements, yes, with some probability, but not really a high probability. If it were done better than the code requirements, which has in fact been the case in the two or three vessels --

COMMISSIONER ROBERTS: Is that what Oconee did?

MR. HANAUER: Yes, sir, they did better than the code.

MR. DENTON: That is a very important area, and by refining that you can reduce the assumed size of the flaws that remain undetected.

COMMISSIONER ROBERTS: It would give you a whole different set of answers.

MR. DENTON: They would permit higher and higher vessel irradiations. The standard assumption came out of our research program in which people looked at under-clad cracks assuming that the standard sorts of fabrication techniques and ultrasonic techniques were used. The distribution ranges from very small ones right up to, I guess, ones that are as big as an inch or so in depth.

It is interest that such cracks are occasionally found under cladding, so they can't be discounted, but it is a conservative assumption in this model. Plant by plant surveillance could reduce those types of conservatisms.

COMMISSIONER GILINSKY: What do we make out of this?

MR. HANAUER: This page 8 diagram is, again, a pressure/temperature diagram. These lines delineate a region for which there is cracking on the left and no cracking on the right. The temperature is plotted as the temperature of the cool-down, T-final, in that stylized cool-down, minus RTNDT, the characteristic referenced temperature of the vessel which characterizes the transition between brittle and ductile behavior.

(Commissioner Roberts left the meeting.)

Now if that were a perfect description of the vessel, all those curves would coalesce to one, but there are effects. There is a pressure effect, which makes these lines slope. There is a small temperature effect, which you see down here at the bottom. Those lines are only 10 or 20 degrees apart, so that is pretty small. There is a small effect on how fast it cools, which is measured by the beta.

(Commissioner Roberts returned to the meeting.)

CHAIRMAN PALLADINO: I am sorry, but you are going just a little too fast for me.

MR. HANAUER: All right. Suppose we have an over-cooling transient --

CHAIRMAN PALLADINO: You were trying to tell me about he 10 degrees, and I didn't find 10 degrees.

MR. HANAUER: All right. Suppose you have an over-cooling transient that goes down to some temperature, let's say 300 degrees.

CHAIRMAN PALLADINO: All right, which one do I want to look at?

MR. HANAUER: All right. That depends on the state of your vessel. If you have a 300-degree vessel --

CHAIRMAN PALLADINO: I see here it says, "TF 300 degrees."

MR. HANAUER: Yes.

CHAIRMAN PALLADINO: Do I follow that curve?

MR. HANAUER: Yes, but the same TF minus the vessel properties. If you have a 300-degree vessel, you go over here to zero.

CHAIRMAN PALLADINO: Yes.

MR. HANAUER: If you have better vessel, a better vessel has a better RTNDT, you would go to the left here.

CHAIRMAN PALLADINO: With a better vessel.

MR. HANAUER: A better vessel is on the left.

CHAIRMAN PALLADINO: Yes.

MR. HANAUER: I am sorry. A better vessel is on the right, and it is less likely to crack.

CHAIRMAN PALLADINO: It depends on which way you want to look at it.

Let me see if I understand what you are saying. If my referenced NDT were exactly equal to 300 -- and I am taking the 300 curve -- then does this say that I could accommodate a pressure of 2000 psi without cracking, or roughly?

MR. HANAUER: Yes, that is what it says.

CHAIRMAN PALLADINO: Now if I go to 150 degrees, it says --

MR. HANAUER: Now be careful, 150 degrees --

CHAIRMAN PALLADINO: Let me go to 250 degrees.

MR. HANAUER: All right, 250. Now TF minus RTNDT is minus 50 degrees down across the bottom.

CHAIRMAN PALLADINO: Yes.

MR. HANAUER: You go up to the 250 degree curve, which is in fact right there with you, and it says that you will crack that vessel because you are 50 degrees below the vessel properties.

CHAIRMAN PALLADINO: I am following the 250 degree curve --

MR. HANAUER: You have a 250 degree transient in a 300 degree vessel.

CHAIRMAN PALLADINO: Now I understand, okay, and it would roughly hold 1000 psi.

MR. HANAUER: Yes, if it comes slowly with a low beta.

CHAIRMAN PALLADINO: What is beta?

MR. HANAUER: Beta is t he exponential

constant on page 6.

MR. DENTON: It is the time which it takes to reach the final temperature, time constant.

CHAIRMAN PALLADINO: Which is faster?

MR. HANAUER: Large betas are faster.

CHAIRMAN PALLADINO: So I am over to the right, and I am not as good as the one over to the left?

MR. HANAUER: That is right, because the over-cooling comes faster and the thermal stress is greater. You see, there is a thermal stress, which is determined by the temperatures and beta, and a pressure stress which is determined by the pressure.

CHAIRMAN PALLADINO: So if I take my 250 curve and a 300-degree reference temperature, I couldn't hold any pressure.

MR. HANAUER: That is right.

CHAIRMAN PALLADINO: Okay.

MR. HANAUER: Very crudely, you can stand a transient more or less down to the referenced temperature. In fact, our more refined calculations say that you can go below the referenced temperature by a few degrees, less than 100. This is a very conservative curve. It assumes that there is a flaw right in the cold place.

COMMISSIONER GILINSKY: Are you talking about crack initiation or crack propagation?

CHAIRMAN PALLADINO: I think he talks of initiation.

MR. HANAUER: In the dictionary sense, it is propagation, but the crack-folks call it initiation. The picture is, there is a pre-existing flaw, and this transient makes the flaw run or propagate, which the fracture mechanics people call initiate. It is a confusing terminology.

COMMISSIONER GILINSKY: I am a little bit troubled by where you have drawn the line earlier as delineating the acceptable region in that we discussed transients which go to temperatures below that.

MR. HANAUER: That is correct. There have been transients which would have cracked this vessel, as shown on those pages, namely, a vessel that has a 270-degree RTNDT in the axial welds or a 300-degree in the circumferential welds.

COMMISSIONER GILINSKY: So you are drawing the line, or you are proposing a line at a level that would not have coped with all the ones that we have experienced?

MR. HANAUER: Would not, in this conservative picture, have coped. Later, I will show you some probabilistic fracture mechanics which give a brighter story.

CHAIRMAN PALLADINO: Steve, you are making, or maybe you are not, let me ask you. Are you making an assumption that all the material throughout the thickness has the same heat temperature?

MR. HANAUER: No, sir. This is quite a complicated calculation. It gives the variation of material properties through the wall because of the different irradiation, including accounting for the change in the neutron spectrum. It also give the change in the material properties during the transient because different parts of the wall are different temperatures. It accounts for these facts as a function of position in the wall.

CHAIRMAN PALLADINO: The running characteristics, though, of a crack are different.

MR. HANAUER: Yes. They are dependent on irradiation and temperature, and both of these functions are in this model.

COMMISSIONER ROBERTS: Are these vessel stressed relieved at original manufacture?

MR. HANAUER: Yes, sir.

MR. DENTON: When we started this about a year ago, there were considerable differences between industry and ourselves on how to do these types of calculations. I think now, at least with regard to Westinghouse, in calculation of crack initiation, we are in very close agreement between the staff and the industry.

MR. HANAUER: Yes.

MR. DENTON: This is not the basis on which we are making recommendations today. It is a more refined curve later in the presentation that we put in more realistic assumptions in certain aspects.

COMMISSIONER GILINSKY: I gather a less conservative model.

MR. HANAUER: Yes.

MR. DENTON: With regard to the type of cracks.

MR. HANAUER: Page 9 shows --

COMMISSIONER GILINSKY: It does seem to me that if we are going to be conservative about anything, this problem sounds like a candidate for being conservative.

MR. DENTON: We agree and we think we are. We will try to show you why.

MR. HANAUER: Page 9 shows the only significant difference that I understand to exist between us and the industry, and that is in the shape of the initial flaw and in the shape in which the flaw expands or propagates.

The right-hand side is the proposal by the Westinghouse Owners Group. They propose that the initial flaw be assumed to be six to one, that is to say, a long, shallow elipse, and that the flaw enlarge in the same shape as shown by curve A.

The original model, the model which we used and still use, is shown on the left, where we assume that the flaw is infinitely long, a convenient mathematical abstraction, and that it grows as an infinitely long crack.

CHAIRMAN PALLADINO: The depth in both cases is the same?

MR. HANAUER: The depth is the parameter that you use to characterize your crack. Depending on what you are doing, you have different assumptions.

Now, in order to figure out how important this difference is, Westinghouse made some calculations. They first made them in accordance with these curve-shaped A. They then made them their elipticle shaped initial flaw, but assuming that it propagates like B. Once the crack starts to run, it becomes infinitely long. The third set of calculations they made was using our model, and their calculations using our model gave results very close to our results. The total difference between their model and our model is about 100 degrees, so it is really very significant indeed.

COMMISSIONER GILINSKY: A hundred degrees in what?

MR. HANAUER: That is to say, if you do a fracture mechanics model and you ask which vessels will crack, assuming the Westinghouse flaw gives you 100 degrees more margin than assuming the infinite staff flaw.

We think the initial Westinghouse flaw is probably more realistic than ours. That the initial flaw is more apt to be an elipse, or something fairly short.

COMMISSIONER ROBERTS: It is certainly not going to be of infinite length.

MR. HANAUER: No, sir.

COMMISSIONER ROBERTS: You just said that it was convenient mathematically for your model, but that does not in any way mean that it is realistic.

MR. HANAUER: That is correct.

We think, however, that once they start to run, that they will get quite long, and there is a good deal of experimental evidence from the Heavy Section

Steel Technology Program that this is true, although infinity is still a mathematical abstraction.

If you look at these two things abstractly, the difference in the initial flaw, where we think Westinghouse is probably right, is of the order of 10 or 15 degrees.

CHAIRMAN PALLADINO: Say that again, I am sorry.

MR. HANAUER: The difference between Westinghouse and us, in the initial flaw shape, is only worth about 10 or 15 degrees.

COMMISSIONER GILINSKY: The effect of the initial flaw?

MR. HANAUER: Yes, the effect of the different shapes on the calculated failure.

CHAIRMAN PALLADINO: I am remembering the 100 you just said.

COMMISSIONER GILINSKY: He is going to get to that.

MR. HANAUER: Yes.

The effect of the shape of the flaw once it starts to go is worth about 85 or 90 degrees. So the difference is primarily in how cracks run and arrest, rather than in how cracks are initially.

My own view is that the Westinghouse initial crack is probably right, more realistic, and therefore this page which I characterized as very conservative is probably about 10 or 15 degrees conservative for this reason alone.

The evidence from the Heavy Section Steel Program is that the reality is closer to the infinite crack than to the short Westinghouse crack. So my own view is that we should not give that large credit for the Westinghouse crack shape.

The industry, or the Westinghouse Owners Group's reply to this has been that they think that the shorter crack shape is correct. They have a program underway to demonstrate this, but it is apt to take more than a year's research to show that it is true.

COMMISSIONER ROBERTS: Is it on-going?

MR. HANAUER: I don't guess I know whether it is actually on-going or not. Perhaps there will be somebody in the room who will know.

MR. DENTON: Let us provide that, Commissioner.

COMMISSIONER GILINSKY: There is somebody coming up.

MR. SAROFF (Westinghouse): I am Ray Saroff from Westinghouse.

We do have an on-going Program under the auspices of the Westinghouse Owners Group to look at flaw shape growth characteristics. As Dr. Hanauer indicated, that program extends through 1983.

There are other programs within the heavy section steel technology at Oakridge that we think will also produce data that will provide more realistic growth characteristics for flaws as they extend. Again, those are not scheduled for completion before the end of 1983.

As that data is accumulated, I think we will have a more realistic picture of how the flaws extend. But both programs are on-going.

CHAIRMAN PALLADINO: Thank you.

MR. HANAUER: Page 10 gives the result of applying this kind of a model to the eight over-cooling transients which have actually occurred.

COMMISSIONER GILINSKY: Would you just list those eight?

MR. HANAUER: They are listed in this enclosure.

CHAIRMAN PALLADINO: When you say, this kind of a model --

MR. HANAUER: Enclosure A.

CHAIRMAN PALLADINO: When you say, this kind of a model, you mean starting with the elipse and going to --

MR. HANAUER: No, sir. These calculations were done with the infinite crack. So they are 10 to 15 degrees conservative.

The dotted curve on page 10 is the curve you saw before plotted in final temperature terms. It runs from about 225 degrees up to about 350 degrees. The solid curve, what we did was, we took each transient as it actually occurs, ups and downs and all, and used it with this fracture mechanics model, and asked what vessel at this plant, experiencing this transient, using this conservative model, would have cracked.

So for the solid curve, these are values of the reference temperature, the RTNDT, which these transients, using this model, would have cracked.

CHAIRMAN PALLADINO: What is the bottom one; that is the final temperature, is that right?

MR. HANAUER: The dotted curve is the final fluid temperature that we talked about earlier.

CHAIRMAN PALLADINO: So now if they go up at 350 degrees, what does this mean?

MR. HANAUER: This says that the chance of getting a transient that goes down to 350 degrees is about two times 10 to the minus 2. If you have a 350 degree vessel, the probability of cracking it from these eight events, with this conservative model, is just about 10 to the minus 2.

What this is is an evaluation of experience of the transients that we have had, and we asked, for each transient, how bad would the vessel have had to be to crack. These calculations were done for us by Oakridge National Laboratory.

COMMISSIONER GILINSKY: Did you understand that, Joe?

CHAIRMAN PALLADINO: I am trying. I think I did, but I am not sure.

COMMISSIONER GILINSKY: I would like to hear it again.

MR. HANAUER: Let's take the most severe one, the Rancho Seco transient. The final temperature was 225 degrees. The actual water temperature was 225 degrees.

CHAIRMAN PALLADINO: All right.

MR. HANAUER: Now we ask the code what kind of vessel would that transient have cracked. The answer was, using this model, a 209 degree vessel would have cracked by that event.

CHAIRMAN PALLADINO: Where did you read 209 degrees?

MR. HANAUER: So that the left-hand end of the solid curve is at 209 degrees. There are tables of these in enclosure A to the Commission paper.

CHAIRMAN PALLADINO: You started out with a 225-degree --

MR. HANAUER: The water got down to 225, but it went so fast that a 209 degree vessel would have been cracked because the pressure went back up.

CHAIRMAN PALLADINO: Where do I see the 209?

MR. HANAUER: It is the end of that black line.

CHAIRMAN PALLADINO: I thought I would go up from 225.

MR. HANAUER: That gets you to the end of the dotted line, which is water temperature. There are two curves here.

COMMISSIONER GILINSKY: My dotted line peters out.

CHAIRMAN PALLADINO: My dotted line is sort of blurred.

COMMISSIONER ASSELSTINE: It ends at 250 degrees.

MR. HANAUER: Pardon me.

CHAIRMAN PALLADINO: I am sorry, at 225 degrees, I come up and I read a frequency.

MR. HANAUER: Yes, sir, and that is one

accident in 350 reactor years.

CHAIRMAN PALLADINO: All right.

MR. HANAUER: It is about three times 10 to the minus 3.

CHAIRMAN PALLADINO: What would have caused --

MR. HANAUER: It is the worst one we have had. So we have only had one that bad, and that is why it is plotted down at about three times 10 to the minus 3.

CHAIRMAN PALLADINO: Where do I go for 209? I am looking at the dotted curve.

MR. HANAUER: The dotted curve is water temperature, the transient temperature.

CHAIRMAN PALLADINO: What is the solid curve?

MR. HANAUER: The solid curve is vessel properties that would have cracked in those transients.

CHAIRMAN PALLADINO: So these represent two different things.

MR. HANAUER: Yes, sir.

CHAIRMAN PALLADINO: Okay, I didn't catch that.

MR. DENTON: There is a dashed line right above the solid line in the lower left, and the dashed line is the water temperature. It looks like a smudge there, but it is the dashed line.

CHAIRMAN PALLADINO: Okay.

MR. DENTON: It goes down to 225. So taking that, and then turning to the code at Oakridge, they back-calculated what vessel properties would have been required to predict failure.

CHAIRMAN PALLADINO: How did you know that I had to go the left to pick up to 209, or whatever that number is?

MR. DENTON: We plotted the curve.

CHAIRMAN PALLADINO: Why is it worse?

MR. HANAUER: Why is it worse; because that one happened so fast and the pressure was so high.

CHAIRMAN PALLADINO: Is this flat portion the range?

MR. HANAUER: No, sir. You had only eight events, so each event makes a lump in the curve. Generally, your probability curve, which is smooth, but here we are trying to figure out probability from only eight things.

CHAIRMAN PALLADINO: But you said that it went so fast, so I must assume that part of the band has to do with the speed with which they changed the water temperature.

MR. HANAUER: Yes, sir.

CHAIRMAN PALLADINO: So 209 is if I go very fast. If I don't go so fast, it could be anything on that bottom line?

MR. HANAUER: Yes, sir, it could. Even, if you do it slowly enough, it won't crack it at all more or less at any situation. You see this is the thermal stress, so if you go slowly enough nothing happens.

CHAIRMAN PALLADINO: It depends on your delta T.

MR. HANAUER: Yes.

The next page, number 11, attempts to answer the question: Are reactors alike? The answer is, no, the B&W reactors appear to be different.

The big, tall, hatched curve on the left-hand side, these are statistical spreads, this is another way to try and look at what has already happened. Since we have had only eight events, the statistical precision of what we are doing is very wide, and I have purposely drawn these curves wide so people don't try and get precise answers out of them, because they are not to be found.

We have had these eight events, and we are plotting here the same thing more or less as was plotted in that solid curve on the preceding curve, except instead of plotting one curve now, I have shown the statistical spread which comes about from having had only a few events.

The three worse events have been -- these are the three on the left-hand side of the page -- the three worse events have been in B&W plants. You see, the 209 degree point over there, and the next one, have all been in B&W plants, whereas the other events on the page have been in Westinghouse plants. We have had no severe over-cooling events in Combustion-Engineering plants, but we have so few reactor years that the statistics of that are really very poor.

CHAIRMAN PALLADINO: Steve, you have this big blob here.

MR. HANAUER: Yes.

CHAIRMAN PALLADINO: It has hashed lines going to the right, that is the B&W.

MR. HANAUER: Yes.

CHAIRMAN PALLADINO: What does it tell me? I see a range here of 209 to 285.

MR. HANAUER: Those are the three over-cooling transients we have actually had in B&W plants.

CHAIRMAN PALLADINO: You are saying that the final temperature range was between the 209 and the 285?

MR. HANAUER: Actually, this is plotted in terms of the back-calculated how bad would the vessel have to be, and that is why it is 209.

CHAIRMAN PALLADINO: All right.

MR. DENTON: Many of the meetings that we had with industry dwelt on this point, whether or not there are fundamental differences in the design and operational modes of these plants that we should recognize, and should we treat Westinghouse plants differently from the C-E plants and the B&W plants.

One thing I noticed in these meetings is that the Westinghouse and C-E Owners Groups had a very strong owners group and did tend to get a lot of support from C-E and Westinghouse. As we have discussed during our recent meetings on water level instrumentation. In this area, again, the B&W Owners Group is practically non-existent.

What we are dealing with in the B&W case is a bunch of owners. So we did not have what I call a coherent view of B&W plants from that owners group as we got from Westinghouse, which has a strong owners group, and tended to treat all their Westinghouse plants and all their operating data altogether. So we tended to get, I think, Steve, some individual B&W owners and their data.

MR. HANAUER: That is correct.

COMMISSIONER GILINSKY: Where is this spread?

You say there is a 90 percent confidence interval.

MR. HANAUER: That is the up and down. That is the up and down spread on this. The upper-line is the upper end at 95 percent confidence. The lower-line is the 5 percent confidence.

CHAIRMAN PALLADINO: Which lower line?

MR. HANAUER: Way down there.

COMMISSIONER GILINSKY: This is on the basis of three events?

MR. HANAUER: Yes, sir, and that is why the spread is so wide, and on the basis of the small number of reactors.

COMMISSIONER GILINSKY: I am not sure which distributions you are using.

MR. HANAUER: These are Poisson distributions.

CHAIRMAN PALLADINO: These are small populations.

MR. HANAUER: Yes, they are.

What we did was, we attempted to infer, from what I have been talking about in the last three-quarters of an hour, a tentative screen criterion which we would then test using some probabilistic schemes.

What we had to work with was what you have just seen, and what we concluded from this was that we would pick 270 degrees for longitudinal cracks, which is what all this business has been. We later found out that in some vessels, the circumferential welds are the ones with copper in them.

COMMISSIONER ROBERTS: Did you misspeak? Didn't you mean longitudinal welds?

MR. HANAUER: Yes, sir, thank you.

Although we assume the cracks are in the welds because the welds are the places where the high copper is and where the brittle material is.

CHAIRMAN PALLADINO: Always?

MR. HANAUER: With one possible exception. In one plant, the plate may dominate, but it is not very serious because it is pretty good stuff. So in the problem plants, the problem materials are in the welds.

In some vessels, there aren't any longitudinal welds, and in some other vessels the longitudinal welds are low copper but the circumferential welds are high copper.

A circumferential weld, in which you assume there is a circumferential crack, is a different beast. In the first place, the pressure stresses are only half as high and, in the second place, the crack is curved and so is restrained by the geometry of the vessel.

Therefore, the situation is less severe. We did some calculations and found that there is at least a 30-degree decrease in conservatism justified by that. So given 270 for the longitudinal welds, we picked 300 degrees for the circumferential welds.

COMMISSIONER GILINSKY: How well are these numbers defined?

MR. HANAUER: Very poorly in two respects.

COMMISSIONER GILINSKY: Plus or minus what?

MR. HANAUER: When you go to find out the properties of an individual vessel, the standard deviation is about 30-40 degrees. When you ask, how well are these numbers deduced from the things I just said, the precision is certainly no better than that, and probably worse.

CHAIRMAN PALLADINO: These are the temperatures for the NDT -- These are the NDT referenced temperatures --

MR. HANAUER: Yes, sir.

CHAIRMAN PALLADINO: -- for the longitudinal crack or the circumferential?

MR. HANAUER: Yes, sir.

COMMISSIONER GILINSKY: So, in actual fact, when you pick a number like 270, you may in reality end up with something like 310.

MR. HANAUER: No, sir, because the next page, number 13, shows how we are going to evaluate a specific vessel in a conservative way to avoid just that problem.

Number 13 shows how we are going to decide what the properties are of any given weld in any given vessel. We start with measurements of the original properties of that material, and we call that RT-0, the original reference temperature. Then we make a calculation of the change in the referenced temperature due to the irradiation. And we have, in different vessels, measurements of the neutron fluids and measurements of the material properties, and we have also, to help us, the measurements of all those specimens in all the vessels which delineate the curve better than any one specimen and any one vessel because of the scatter.

CHAIRMAN PALLADINO: Steve, are you characterizing the inner-most fibers of the steel?

MR. HANAUER: Yes. We are characterizing this whole complicated thing.

CHAIRMAN PALLADINO: What I am getting at is the delta RT is not constant through the thickness.

MR. HANAUER: That is right. I am characterizing the whole vessel and the value of RT at the inside wall, and that is how we characterized our calculations. The calculations include the change through the walls, but in order to use one number, we used the number inside. That is not a conservatism because that changes in the calculations that we use to pick it.

CHAIRMAN PALLADINO: Okay.

COMMISSIONER GILINSKY: Let me ask you, isn't there a number 200 which is fixed in our regulations, in Appendix G, as having a certain significance?

MR. HANAUER: The Appendix G has two things in it. One is the upper-shell toughness, that is to say, the toughness of the material in the ductile range, which is also affected by radiation and which we are not dealing with today, but is also the subject of an investigation that has been going on.

The second thing is that there is a provision that the temperature of the vessel -- the pressurization of the vessel and the temperature of the vessel must stay within the bounds dictated by the properties of the vessel. I don't believe that there is a number like 200.

Neal?

MR. MURLEY: Yes, there is. Maybe Neal can explain it further.

The 200 degrees is evaluated at the quarter thickness of the wall, so that it means two inches into the wall. If your vessel is expected to get to 200 degrees during its lifetime, our regulations require that it has to have the capability for annealing.

COMMISSIONER GILINSKY: Do any vessels fall in that category?

CHAIRMAN PALLADINO: You said, if the vessel gets to 200, or do you mean if the referenced temperature.

MR. MURLEY: The referenced temperature of the vessel is calculated to get to 200 degrees a quarter of the way through the wall, that is two inches into the wall, then it has to show the capability to anneal.

CHAIRMAN PALLADINO: It has to what?

MR. MURLEY: It has to have the capability to be annealed.

CHAIRMAN PALLADINO: It is the referenced temperature.

COMMISSIONER GILINSKY: Do any of the vessels in use today fall in that group?

MR. HANAUER: Yes, sir, there are vessels which are predicted to have referenced temperature higher than 200 at quarter-thickness by the end of life.

COMMISSIONER GILINSKY: Are they exempted from this requirement?

MR. HANAUER: No, sir. They have, in fact, made a demonstration that annealing is possible.

CHAIRMAN PALLADINO: What is that 2 to squareroot of sigma zero?

MR. HANAUER: That is two standard deviations and since there are two components, you add the standard deviations as the squareroot of the sum of the squares.

MR. DENTON: This responds, Commissioner Gilinsky, to your concern about conservatism. I think what it shows is that when we are characterizing the vessel, we are taking a conservative view, in my view, of characterizing the properties.

Of course, there is a lot of uncertainty in how you arrive at the correct numbers for doing the screening, but when we go to an individual vessel, this is the way we are determining that vessel's properties, which compensates for some of the uncertainties in the rest of the calculation.

CHAIRMAN PALLADINO: And the delta RT, you get from some empirical data?

MR. HANAUER: Yes. There is a great deal of data shown schematically on page 14, and some of the actual correlation shown on page 15. The Commission has seen some of these before, and perhaps in the interest of time, unless there is a question --

CHAIRMAN PALLADINO: I have one question. If I recall, these vessels have samples of original or similar material in them which can be pulled out and checked --

MR. HANAUER: Yes.

CHAIRMAN PALLADINO: -- which might give you a better handle than some of the general curves on what is happening to the embrittlement.

MR. HANAUER: That is correct.

CHAIRMAN PALLADINO: Are these used to monitor these vessels?

MR. HANAUER: Yes. For each vessel, one marshalls the vessel specific information that is available and also the generic information from all of the samples of that kind of material. We look at both.

CHAIRMAN PALLADINO: Do you show that in any of your proposals?

MR. HANAUER: It is in enclosure A, in one of the appendices, which discusses this question in some detail.

MR. DENTON: When we are talking in these tables about the properties of individual vessels, it does reflect the data that has been derived from those capsules in those plants where such data is available.

CHAIRMAN PALLADINO: You didn't use, maybe that was too detailed. In your general recommendations of what to do in the short-term, the monitoring of those specimens was not mentioned.

MR. HANAUER: That is where all this information came from, Mr. Chairman. That is where the curves came from is evaluation of one of the capsules that had been measured in all of these vessels. What you do in any given vessel is, you find out what you know about that vessel from its own capsules, and also what you know more generally.

The capsules in the specific vessel give you specific information, but the spread on any one measurement is fairly wide. By putting together the measurements of all the similar materials, you establish with better accuracy what the properties are for that family of materials.

CHAIRMAN PALLADINO: Let me buy it for a while.

MR. HANAUER: There is a great deal of work on this, the latest being by Guthrie of the Hanford Engineering Development Laboratory.

COMMISSIONER GILINSKY: I am going to have to leave in a few minutes, but I did hope you could respond a little more to the question of why you think it is okay to set a temperature level which is well above temperatures which have been attained in the various events that we talked about.

MR. HANAUER: The short answer is that our probabilistic calculations show that there was too much conservatism in the assumption of a crack being just where the cold water was, that the probability of that is low. Therefore, the probability of that vessel actually having failed in that transient is quite low. That is why we proposed to set it at that high a value. That is the short answer.

COMMISSIONER GILINSKY: On the basis of some notion of the frequency of cracks?

MR. HANAUER: Yes, sir. There is in our probabilistic model a crack probability distribution based on a number of measurements in which several thousand meters of welds were disected to find all the flaws, and the probability of such flaws being there and not being detected was evaluated.

CHAIRMAN PALLADINO: Steve, could I use your criterion on slide 8 just for a moment. If I go to zero, and I am going to use your 270 degrees number, and I will go over here and stick to the right-hand group, the 270-degree line for the bottom temperature, and since I have got a 270-degree NDT and zero, this would say that I could carry over 2000 psi, or better than 2000.

MR. HANAUER: Yes. A 270-degree transient in a 270-degree vessel, even in this conservative model, could stand high pressure.

The answer to Commissioner Gilinsky's question concerns a 209-degree transient in a 270-degree vessel.

COMMISSIONER GILINSKY: Precisely.

MR. HANAUER: In that case --

CHAIRMAN PALLADINO: Let me follow this one. Let's follow it on slide 8.

MR. HANAUER: You have to go to minus 60 on the apsis.

CHAIRMAN PALLADINO: Okay.

MR. HANAUER: You find that for the large beta, it will crack for any pressure, because you are to the left of the 209-degree curve. But for the small beta, you can go up to 209 and you can stand about 1000 psi.

COMMISSIONER GILINSKY: Let me ask you, in setting the limit, what sort of guidance did you use in deciding how much of a safety margin there ought to be?

MR. HANAUER: I will tell you where we started. We said, we will pick about a 10 to the minus

2 transient, and we will pick a vessel model without a 10 to the minus 4 of wrecking the vessel. At that time, we knew both of those numbers very poorly. We looked at 10 to the minus 2 transients, some of those curves we showed you earlier, and that is a number about 270 degrees.

At that time, we knew very little about whether the vessel failure probability was in fact 10 to the minus 4 or not. We had some early probabilistic fracture mechanics curves. Later on, some of these curves shifted around, and in fact, the 270, if we had stuck to our original basis, could have been 300 or higher. In the meanwhile, we had better probabilistic curves and that told us to stay at about 270.

This is not a precise business. The original choice of the number --

COMMISSIONER GILINSKY: I have not had a chance to go through this six-inches of report, are the assumptions laid out in there?

MR. HANAUER: Yes, sir.

MR. DENTON: They originally were well below the type of safety goal of 10 to the minus 4 that the Commission was talking about, because of the seriousness of this type of failure. We felt that we were in about a one time 10 to the minus 6 space, but very uncertain.

As it has evolved, and Steve has the latest number, which is later in the presentation, but that is what we were kind of shooting for when we first started, to make this a very remote event.

COMMISSIONER GILINSKY: We have talked about this before. A severe break in the vessel is something for which we have not provided protection.

MR. HANAUER: That is correct.

COMMISSIONER GILINSKY: So it is something with which we ought to be extremely careful. I know there is no need to tell you that, but I just wanted to give you my view.

MR. DENTON: The numbers for the screening criterion, Steve has some estimates.

Do you want to turn to those, Steve, and show what they are.

We are also proposing that we take action so that we are not faced with a fait accompli with vessels being right at these limits. If reasonable actions are taken on a number of plants to keep fluence down, and many plants never get to these levels.

We are not talking as though this is a speed limit and we expect every plant to run right up to it. We expect o be actions taken in a number of cases for plants to stay below it.

CHAIRMAN PALLADINO: Some of the plants will run up to that.

MR. DENTON: There is one plant that appears unable to take any fluence reduction action without exceeding it before the end of life, and that is Robinson. There are a few plants which are going to have to take more severe than the normal flux reduction sort of changes.

MR. HANAUER: Why don't we turn to the probabilistic results on page 25.

These are probabilistic results. They have event-trees in them, and system failure probabilities. What we have tried to do is figure out the various ways in which we can get over-cooling transient, and to consider both their probabilities and what they would do.

We also have then a probabilistic model of vessel failure, which I have referred to earlier, which is somewhat complex, but which I can answer the first level of questions on, and Mr. Sneider in the back of the room can answer the second level of questions on, since he did it.

The result is shown in these curves which plot the frequency of vessel failing as a function of the vessel properties. The X axis is the properties of the vessel. This egg-shaped curve at the bottom left here is intended to represent the distribution of vessel properties.

(Commissioner Gilinsky left the meeting.)

You don't really know precisely the vessel properties. So what I have drawn here is a vessel which I evaluate at 270 degrees out at two standard deviations. This vessel is most likely to be a 210-degree vessel because two standard deviations is 60 degrees. The probabilistic fracture mechanics considers not this very conservative value of the vessel, but what the vessel is most likely to be.

CHAIRMAN PALLADINO: Which is 210?

MR. HANAUER: Which is 210. That is to say, we picked the way we evaluate vessels conservatively enough so that a vessel we say is 270 is most likely to be 210, although it can, with some small probability, be 270. That is what this curve -

CHAIRMAN PALLADINO: I wish victor would have heard that, because I was having a little bit the same trouble. I didn't appreciate that.

MR. HANAUER: So, a vessel just at the screening criteria is most likely to be a 210, but can be a 270.

CHAIRMAN PALLADINO: Two sigma is what, 2.67?

MR. HANAUER: No. That is one sigma. Two sigma is .9-something.

CHAIRMAN PALLADINO: Okay, thank you.

MR. HANAUER: The various curves here are for the various kinds of transients. The left-hand curve is the sum.

CHAIRMAN PALLADINO: I am sorry, I was not listening. I was still thinking.

MR. HANAUER: The various curves on page 25 are for various kinds of transients -- steamline breaks, steam generator ruptures, and so on. The left-hand-most curve, the slanty one here, is the sum for all the different kinds of transients.

A new vessel is off on the left-hand side of this thing, and the new vessel has a negligible chance of getting hurt by any of this stuff because it has a referenced temperature that is very low, and the chance of transients down below 200 degree is really pretty small.

As the vessel ages, you have to go toward the right. As the vessel ages, its referenced temperature gets higher.

CHAIRMAN PALLADINO: But always you are talking about a referenced temperature that is the two sigma temperature?

MR. HANAUER: You can talk about either one. The numbers here are for the most probably, not for the two sigma.

CHAIRMAN PALLADINO: Wait a minute, then. I am sorry. Let's go to 270 again.

MR. HANAUER: Yes.

CHAIRMAN PALLADINO: Let's go up to your top-most curve.

MR. HANAUER: Yes. If we have a 270 degree vessel, and it is really a 270-degree vessel, then the chance or the frequency of cracking it from pressurized thermal shock in this model is about 10 to the minus 4 per reactor year.

CHAIRMAN PALLADINO: Ten to the minus 4?

MR. HANAUER: Yes, it goes up here to about 10 to the minus 4.

CHAIRMAN PALLADINO: I can't read that. Yes, okay.

Then what is all this other stuff you were telling me about with the two sigma.

MR. HANAUER: A vessel which just gets to the screening criterion, I evaluate not at its most probably value, but two sigma.

CHAIRMAN PALLADINO: So far as frequency is concerned, it is whatever --

MR. HANAUER: It is whatever it, which we still don't know very well. The most probable value for that vessel just at the screening criterion is, in fact, 210.

CHAIRMAN PALLADINO: When you put the frequency curves on, you don't use the same temperature. You use whatever the temperature is.

MR. HANAUER: Yes.

CHAIRMAN PALLADINO: Does that say that if I take my 270 one, I should go up here, really, and look at 210?

MR. HANAUER: Yes, sir. That is the point of that lower curve, and at 210, the failure probability from pressurized thermal shock is something below 10 to the minus 5.

CHAIRMAN PALLADINO: Okay.

MR. HANAUER: It is this kind of thing that said don't move up over 270. If you would like a little more conservatism, you get about a factor of 10 for each 35 or 40 degrees. If you would like them to be more conservative by a factor of 10, then move down from 270 down to about a 235. That brings you down just a little off the left-hand side of the page. That brings you from the 10 to the minus 5 range into the 10 to the minus 6 range.

MR. DENTON: One other point, Steve, just to be sure we are conveying the right information. On this curve, it was done using our infinite crack length model. We have talked about those conservatisms before.

This model has a crack distribution in it that is the same crack distribution that came out of the so-called Octavia code. So it has an assumed distribution of cracks in the vessel, but the cracks are assumed infinitely long. That is the basis for this calculation.

CHAIRMAN PALLADINO: An assumed distribution of cracks, explain what you mean by that.

MR. HANAUER: In the probabilistic model, we have a model for the probability of there being a crack of various sizes, a crack size probability distribution. This is fairly high for very small cracks, which you get when you put the beading on, and it is very low for larger cracks.

CHAIRMAN PALLADINO: I am sorry, I didn't understand that.

MR. HANAUER: Our conclusions are on page 28. I will not quite read them.

We believe that vessels at or below the screening criterion are acceptable. Vessels above the criterion may be acceptable, but it takes much more analysis for them than this generic stuff that we have been doing. That is to say, we think we have a good position that vessels below the screening criterion, because of all these conservatisms, are surely okay with high probability.

For vessels that reach the screening criterion, or are predicted to reach it, we think that there should be a plant specific analysis to look into some of these things which were done generically and without a lot of precision.

Most of the plants will or can be made to stay below the screening criterion throughout their lives by flux reduction measures, which different amounts in different plants. To get a reduction up to a factor of two is essentially free.

CHAIRMAN PALLADINO: It is free?

MR. HANAUER: It is free, and in fact some plants have gone to this in order to get the benefits of an 18-month cycle. So there are plants that have already done this for other reasons.

CHAIRMAN PALLADINO: What do you mean, it is free?

MR. HANAUER: You will have to pay more for the fuel, but you get an 18-month cycle instead of a

12-month cycle, so you save money on down-time.

CHAIRMAN PALLADINO: What are you doing physically?

MR. HANAUER: What you do physically, you load the twice-burned fuel in the outside row.

CHAIRMAN PALLADINO: The which?

MR. HANAUER: You load the burnt down fuel in the outside row. This has advantages for fuel cycle, and at the same time it reduces the leakage flux, it reduces the embrittlement of the vessel. Nothing in life is free, but the cost seems to be low and some plants have chosen to do it on the basis of savings in down-time.

If you need more than a factor of two, as a few plants do, then one would have to evaluate on a plant specific basis how much you could get without running into some other limits.

As you reduce the leakage flux more and more, you effectively make the core smaller and smaller, and you make the center of the fuel work harder and harder, because the outside of the fuel is working less and less.

CHAIRMAN PALLADINO: What do you do, you put more burnt out fuel?

MR. HANAUER: Yes. If that isn't enough, then you put dummy fuel in the outer-row. In Finland, where they turned out to have a very susceptible vessel, and in some German plants, they have replaced the entire outer-row of fuel with stainless steel dummies, but this involved some derating.

CHAIRMAN PALLADINO: Yes, I was going to say where --

MR. HANAUER: We have a series of calculations. The details are given in enclosure A. Appendix I gives a series of calculations as to what can be done and what some of the deratings and prices might be if you need more than a factor of two.

CHAIRMAN PALLADINO: Is the derating significant? I have not looked at of those curves.

MR. HANAUER: Yes, sir, the derating can be significant. Our calculations show that you may be able to get as high as a factor of four without derating. But now you are into such plant specific questions as to hot channel factors, and loading patterns, and so on that we are in a grey area where we would have to have plant specific information in order to get a --

CHAIRMAN PALLADINO: I am surprised you don't get into trouble before that.

MR. HANAUER: Apparently not. H.B. Robinson, for example, has already initiated -- reloaded with a low flux factor of two reduction and did not have to derate the core.

CHAIRMAN PALLADINO: A factor of how much?

MR. HANAUER: Two.

CHAIRMAN PALLADINO: No, I said, when you get to four.

MR. HANAUER: When you get to three or four, we have some calculations which suggest that most plants can do it, but we don't really know until we look plant specific. We know, for example, or we are told by Carolina Power & Light that the factor of two is the limit for that core, which is being pushed pretty hard.

COMMISSIONER ASSELSTINE: Is that strictly by fuel management?

MR. HANAUER: It is fuel management, but the limit is imposed by safety limits on the peak power density and the calculated consequences of some accidents and transients. Which accidents and transients dominate depends on the reactor. Sometimes it is loss of coolant accidents, and sometimes it is the pump transients.

CHAIRMAN PALLADINO: How has derating been a factor in the estimate of cost, or hasn't it?

MR. HANAUER: It has. We have estimated, on the basis that no derating is required, up to a factor of four, but we know that above two that is subject to correction, and we would have to look at it plant by plant.

We also recommend that most plants can stay below the screening criteria throughout their lives by flux derating, and we believe that it is prudent that this be done in most plants. This is a real safety improvement in these plants. It actually slows down the embrittlement and keeps it in the acceptable region. Whereas the other alternatives, if this option is not taken, are either potentially very costly or they are pencil-sharpening exercises to show that the increasingly embrittled vessel is, in fact, satisfactory.

The reason for emphasizing flux reduction is that the embrittlement of the vessel is cumulative, and that flux reduction to be effective has to be done in a timely way. For vessels which need a factor of two or less, a year more or less doesn't matter very much. For the vessels which are more embrittled than that, a timely flux reduction might be feasible now, whereas later on that option would be foreclosed.

The Commission would be presented later on with a fait accompli, where the options would be either to show that a more brittle vessel was all right, to do things like improve control systems, heat the emergency core cooling water.

CHAIRMAN PALLADINO: I was going to ask you about that one.

MR. HANAUER: At Robinson, they have committed to do that.

CHAIRMAN PALLADINO: What is the normal water temperature that you are assuming in these analyses?

MR. HANAUER: The assumption in the analysis that we did was that the water was at 60 degrees. Many tech specs require that the water be kept above 40 degrees, or above 60 degrees, and in northern climates there is already some heating in that water.

There is also a maximum temperature on that water because it is used for core cooling, and if it gets too hot, it doesn't cool. But that maximum is way above the range that I am talking about.

You get just about degree for degree improvement in safety by warming this water in this range. The proposal by Carolina Power & Light is to make sure the water stays above 80 degrees, which gives a 20-degree benefit in the safety record in this way, and would push them 20 degrees further on the good side of that probability curve.

CHAIRMAN PALLADINO: Why did you stop at 80?

MR. HANAUER: That is their proposal.

CHAIRMAN PALLADINO: But you are saying that the tech specs could allow them to go up higher?

MR. HANAUER: The tech specs allow them to go up higher.

CHAIRMAN PALLADINO: How much higher, 100?

MR. HANAUER: I don't know what the limit is at Carolina.

CHAIRMAN PALLADINO: I am only trying to get a feel.

MR. HANAUER: It is petty high. In general, it is not a problem, because in general the tanks are outside, and something like 100 degrees is as high as they would ever get, even in Carolina.

CHAIRMAN PALLADINO: Why not take advantage of that?

MR. HANAUER: That is one of the options.

MR. DENTON: That is not the only limiting transient either. That works for those transients where that water is controlling the temperature. There are other kinds of transients that eventually would become dominant and further heating would not solve the problem.

COMMISSIONER ASSELSTINE: As I read the proposals, you had a set of near-term actions and a set of longer-term actions. The near-term actions were aimed principally at flux reduction. Is the idea that what you do is minimize the extent to which the problem gets worse over the near-term?

MR. HANAUER: That was our objective.

Flux reduction is not an irrevocable measure. If later on, some research program shows that we were too conservative, then at the next loading they could pay less attention to that if it turned out to be more economical.

CHAIRMAN PALLADINO: Are all options, other than flux reduction, closed out so far?

MR. HANAUER: No, sir, there are other options. They tend to be more expensive than flux reduction for most plants.

The plant we have looked closest at, to look at the options, is H.B. Robinson, which is by far the most embrittled plant at the present time. Carolina Power & Light has come in with a multi-front program to cope with this question.

The first thing they did, which has already been accomplished, is to reduce the flux by a factor of two, which they believe to be the practical limit in that plant without derating. The next thing they have committed to do --

CHAIRMAN PALLADINO: Did they look to see how much derating they would have to do to try to get a factor of four?

MR. HANAUER: I don't have such a number from them.

CHAIRMAN PALLADINO: Did they look at that?

MR. HANAUER: I don't know. They have told us informally that any more flux reduction than a factor of two would involve derating, but they haven't told me -- I don't know of any number from them.

CHAIRMAN PALLADINO: I was thinking, if they extend their life significantly, maybe a small derating wouldn't hurt them. It is a balance of cost.

MR. HANAUER: It is, indeed. It is, indeed.

Nor do we have for that plant how much rating would be required. In fact, there isn't any reasonable flux rating that will get H.B. Robinson to the end of life because they are already within 20 degrees of the screening criterion.

COMMISSIONER ROBERTS: How confident are you of the accuracy of the RTNDT for Robinson?

MR. HANAUER: We think it has an error band or standard deviation of about 30 degrees. It is much better known than the range of over-cooling accidents. The error band, the uncertainty band on the vessel properties exists and is significant, but the unknown, the uncertainty in the kinds of over-cooling transients is rather large and dominates the question. But, both have to be considered.

COMMISSIONER ROBERTS: It looks to me like you make a radical change. This viewgraph has conclusions, but in the paper we have got here, you are going to issue a show cause order to them.

As late as September, in your draft report, and when you appeared before the ACRS, there was never any such talk as this. Now, what has changed that has changed your mind? I can't believe anything in a two-month interval, as far as you know or don't know, could have changed.

MR. HANAUER: What changed our mind is a better look at the options and the realization that some of the calculations, which we have, were not realistic. The realization that no doable amount of flux reduction would get H.B. Robinson to the end of its life within the criterion.

The show cause order, the answer to such a show cause order would presumably be a plant specific evaluation which would, in fact, give the basis on which further operation would be justified. Carolina Power & Light has told us what their plans for making such an evaluation.

Besides the flux reduction that they have already done, the water warming, which they are committed to do, they have also proposed to do an evaluation of transients and to look into the possibility of measuring better the actual properties of their vessel than is implied by the 30 degree uncertainty which I told you about.

COMMISSIONER ROBERTS: Why have a show cause order?

CHAIRMAN PALLADINO: That is what I was wondering. Why do we need a show cause order? They are not in any dangerous state as far the criteria.

COMMISSIONER ROBERTS: That is what makes headlines.

MR. HANAUER: They are calculated to reach the screening criterion in a time period of five to seven years from now. So that a show cause order would not imply there is any immediate danger, but that a program --

COMMISSIONER ROBERTS: They are not derate, and that is not realistic, and you know that.

CHAIRMAN PALLADINO: But, Steve, if they are committed to do all the things you want them to do, why do you need a show cause order?

MR. DENTON: By committed, we have only, since we sent the paper down, gotten verbal commitments. They have not committed yet on the docket to do these things. So we have been twisting their arm.

We think they can get through the cycle they are in, but it is clear that they need a very ambitious program to couple low leakage cores. They need plant specific analyses. They need to look very carefully at their surveillance specimens. They have a number of actions that they can do to really pindown how good their vessel is.

What we wanted to do was to get this from them. If they volunteer it, then maybe we won't need it. But as of today --

MR. HANAUER: We want it on the record.

COMMISSIONER ROBERTS: Are we reacting to various pressures on this agency, or are we evaluating a factual situation?

MR. DENTON: As an advocate of the position, I thought that we should not wait until they get to 270 and then be confronted with a "either let me operate or don't" kind of situation. We see that they were not moving as fast in this area, or as aggressively, as we thought they should.

They have moved along considerably since we have started in the last month. We thought, when we put this paper together, that we might have to force them to propose a program to resolve it before they got to the point of going above the criteria. If they are willing to cooperate and do it otherwise, that is fine also.

CHAIRMAN PALLADINO: Couldn't we do it with a 50.54(f) letter?

MR. DENTON: It depends on the willingness of the utility to do it. We could certainly start that way.

CHAIRMAN PALLADINO: Don't they have to respond to a 50.54(f) letter?

MR. DENTON: Yes.

CHAIRMAN PALLADINO: A show cause order is a pretty drastic move, and you take it for drastic circumstances. If there was no other way to get them to move, then that would be different. But it sounds like they are moving, and if we can accomplish it with a 50.54(f) letter, I wonder why do it with a show cause.

MR. DENTON: I think it is --

CHAIRMAN PALLADINO: Maybe the circumstances have changed such that you might want to consider that.

MR. DENTON: We will consider it. The proposal that is before us, I think we consider still lacking some depth in covering all of the bases that are needed to provide the kind of assurance we will need when they get to cycle 10 and 11.

We all agree that they are a few years away from tripping the limit, and we think they need to mount this sort of aggressive program today, and if they would volunteer that kind of program that would provide the information we need. I just didn't want to get out to '84 or '85, and then not have the information available to make an informed decision.

CHAIRMAN PALLADINO: I don't think anyone is taking exception with trying to get action in that direction, it is the vehicle for doing it. I know Commissioner Ahearne, he can speak for himself when he comes back, is quite concerned about that route also, if it can be accomplished by a 50.54(f) letter, or some other means, more imaginative means that you might develop.

MR. DENTON: We could sure consider that.

Steve, would you like to comment on that program, how you see it as it has been outlined to date?

MR. HANAUER: The program has been orally desc[illegible] to us with some viewgraphs in a half-day meet[illegible]ng o[illegible] about three weeks ago. It contains a number of aspects, a number of facts, including the one they have already performed, the flux reduction, and the one they have they will do, namely, to heat the water.

It also include plant specific analysis of one transient, which is being done in collaboration with the Electric Power Research Institute, and collaboration with one of our research programs in doing a more detailed probabilistic analysis.

But the delineation of when these products will become available and what the options are for plant modifications, if they are needed, has not yet been developed, and we have not seen a fully developed program commensurate with the embrittled state of this vessel. We think that there probably will be such a program, and we would like to see it progress.

MR. DENTON: We were just trying to put together a structured response. There are many plants which will not exceed these criteria even at the end of life. Then we saw that Robinson was the highest and needed the most assurance that we would be able to deal with that.

Then there were some in the other class, and we proposed the 50-54(f) letter as a way of dealing with those. Then for the few that may need some moderate flux reduction programs, we would propose a rule to the Commission within the next six months, that could be issued as a proposed rule that would deal with making sure that the great bulk of those plants do take those flux reduction measures at the appropriate time.

CHAIRMAN PALLADINO: I still had the question why a 50.54(f) letter would not be appropriate.

MR. DENTON: That could be used. That is always the first issue. Then if what you get back is not satisfactory, you can proceed further.

MR. HANAUER: This is, perhaps, a suitable finish in view of the time. I believe the important questions have been explored, and we are available for further questions and discussions, Mr. Chairman.

CHAIRMAN PALLADINO: I am looking over the list of questions. I have gotten most of mine answered along the way, and a few that I won't bother with today, but I might bother with at some later time.

What degree of industry activity do we have in the long-term program?

MR. HANAUER: The long-term industry program --

CHAIRMAN PALLADINO: What share of the burden are they taking?

MR. HANAUER: There are several industry programs. There is the Electric Power Institute research program in presssurized thermal shock, which includes vessel properties and the development of methods for analyzing over-cooling transients.

The owners groups, there has been a very extensive Westinghouse Owners Group program which is substantially responsible for the probabilistic insights that we have achieved since May and June, when this was first presented to us by the Westinghouse Owners Group.

The Combustion-Engineering Owners Group also has a program in both vessel material properties and in the transient analysis.

B&W has completed a very extensive, perhaps the most extensive review of vessel material properties, but very little other activity is known to us by the owners group.

The plants, which are principally affected -- they know very well who they are, and they tend to be the leaders of the owners groups -- are doing plant specific analyses in some areas.

There are also in the owners groups additional research programs, such as the one that Mr. Seroff described to you earlier in the afternoon on crack shape in answer to your question. There are a substantial number of those programs that have been reported to us, and there are no doubt others which are not yet in a state to be talked about.

There is also substantial cooperation by three plants in the NRC research program into over-cooling transients, which is being led by Oakridge National Laboratory. Also there is participation by Los Alamos and Idaho Nuclear Engineering Laboratories in quite elaborate calculations of over-cooling transient probabilities, and the course and severities.

In order to be specific about these, we have chosen to study three specific pressurized water reactors. Oconee, for the B&W plants, is the first one which is well underway. The Westinghouse plant is to be H.B. Robinson and Carolina Power & Light, and we are collaborating, and some of that information will surely be part of the basis for the safety evaluation of the Carolina Power & Light Robinson plant. The third plant is Calvert Cliffs, which is representative of the Combustion design.

We are evaluating in our research program, in this collaborative way, these three plants of different designs to get insights into whether the generic requirements should in any way be changed. This is a multi-year program, which has completed about the first year.

There is also the very large heavy section steel technology program, contributions by the pressure vessel research Committee of the industry, which has been going on for nearly 20 years, which has already done a substantial number of thermal shock experiments, and which is now getting ready to do some pressurized thermal shock experiments in large model vessels.

CHAIRMAN PALLADINO: Is anybody looking into the feasibility of an answer to annealing?

MR. HANAUER: There is a program underway, under our auspices, at Idaho, to look into the feasibility and the costs and benefits. We have a preliminary report from them, and research is within a few weeks of making a recommendation to us on whether such a test would be feasible, and whether it would be cost effective.

CHAIRMAN PALLADINO: Whether a test --

MR. HANAUER: Whether an annealing demonstration test --

The metallurgy of the annealing process seems rather well-known. What is not known is whether it is in fact a practical and a practicable procedure, and whether it introduces any safety questions that would have to be resolved, which would give a downside to what would otherwise be a safety improvement, although it is believed to be quite an expensive one.

COMMISSIONER ROBERTS: Inexpensive?

MR. HANAUER: An expensive one.

CHAIRMAN PALLADINO: I just wanted to make sure of that.

MR. HANAUER: Yes.

CHAIRMAN PALLADINO: If it is cost effective, or if you lose more not doing it than doing it, the answer will come out differently.

I had another question, but I forgot it. Do you have any questions, Tom?

COMMISSIONER ROBERTS: Most of mine have been answered.

COMMISSIONER ASSELSTINE: I have one.

CHAIRMAN PALLADINO: Go ahead, Jim.

COMMISSIONER ASSELSTINE: The only question I have is for the near-term actions on this middle category of plants, not Robinson and not those where over the lifetime the level can be kept in acceptable ranges simply by fuel management.

For the ones that you might have to use the dummy assemblies. Is there general agreement from those licensees of about eight plants that this is the best alternative for the short-term?

MR. HANAUER: No, sir. They have rather recently received our calculations and they have now, today, with the public distribution of this version of this report, which has some new data in it -- They have just today gotten the details of the basis for our recommendations.

We have no plant specific analyses of these eight plants, although there have been many fuel management calculations for them, I am sure. We don't know whether our generic calculations in fact fit the circumstances of these eight plants. And we have not had a dialogue, we need one, and we intend to have one with these eight plants.

COMMISSIONER ASSELSTINE: I guess one of the things I was wondering was to what extent they might want to come in with a proposal somewhat like the heating of the ECCS water, for example, as an alternative to installing dummy assemblies.

MR. HANAUER: We don't know.

We would welcome an exploration of alternatives in these plants.

COMMISSIONER ASSELSTINE: So you are not necessarily locking them into the alternative that you have described here. If they want to come in with an alternative proposals that would involve some of that, but perhaps other alternatives as well, that would be within what you have in mind here?

MR. HANAUER: That is correct.

But for those plants, a fairly prompt

evaluation would be appropriate in order not to foreclose some options.

COMMISSIONER ASSELSTINE: Okay.

CHAIRMAN PALLADINO: But heating the water doesn't cover all the circumstances.

MR. HANAUER: It doesn't cover all the circumstances. For the Westinghouse plants --

CHAIRMAN PALLADINO: But it may cover the circumstances of significance to that plant.

MR. HANAUER: The analysis we have is for Westinghouse plants, and that analysis in its present state of maturity or immaturity shows that the dominant event would be helped by heating the water. But I would not want to call this a mature evaluation.

The fact that we have a new set of sequences every month is clear evidence to me that the evaluation needs to be continued and matured to the point where we have general agreement that we have all the right sequences in there, and that they have been evaluated realistically.

CHAIRMAN PALLADINO: Steve --

MR. HANAUER: Let me say one more thought on that.

I want to emphasize to emphasize that what we have is a Westinghouse analysis. The C-E plants are similar and we feel that the adequacy of these analyses in their present shape is satisfactory for the C-E plants, although we are more than willing to see a more complete C-E plant analysis.

The difference in response of the B&W plants, and the difference in experience in the B&W plants, makes this situation a lot less rosy for the B&W plants and we do not have the same degree of assurance for them. Two of the eight plants you mentioned are B&W plants, and it is our plan to use them as lead plants for exploring these questions in B&W plants.

COMMISSIONER ASSELSTINE: So the emphasis, really, for these eight plants is to get an analysis, a detailed analysis, a satisfactory analysis as soon as possible right in the near-term and look at what the plans are for B&W plants.

MR. HANAUER: Yes, sir, this is our intention.

CHAIRMAN PALLADINO: Steve, you said some of the plants, you are clear, won't need any corrective action before the end of the life, and others like Robinson need something soon. Do we have an analysis in this report?

MR. HANAUER: Yes, sir, you have detailed tables in the report, and you have in this handout the table which starts on page 16.

CHAIRMAN PALLADINO: They are small numbers, small print.

MR. HANAUER: Sorry about that, Mr. Chairman.

CHAIRMAN PALLADINO: Thank you.

MR. HANAUER: The right-hand three typewritten columns are ours, and the licensees' evaluation of the present state of the vessel, and the right-hand handwritten column for a few plants is our evaluation of when they are likely to get to the screening criterion.

CHAIRMAN PALLADINO: What is the heading there?

MR. HANAUER: Year exceed screening RT.

CHAIRMAN PALLADINO: That did not come clear, and maybe I can get a better copy.

MR. HANAUER: A more detailed evaluation --

COMMISSIONER ROBERTS: There is an error in this.

MR. HANAUER: Which one, sir?

COMMISSIONER ROBERTS: They are not all on unit 1.

CHAIRMAN PALLADINO: What page?

COMMISSIONER ROBERTS: Page 16, in the handwritten column.

MR. HANAUER: It says 1995.

COMMISSIONER ROBERTS: Mine reads 1975.

CHAIRMAN PALLADINO: We need better copies.

MR. HANAUER: You shall have a better copy if we can provide it.

CHAIRMAN PALLADINO: Even if we get somebody to darken those numbers, so that we can see them.

MR. HANAUER: Somebody down here has the original, which has those numbers darker, and that can presumably be provided to you. I think the original is down here.

CHAIRMAN PALLADINO: All right, we will get it.

MR. HANAUER: If you need help from us, we will be glad to supply it.

CHAIRMAN PALLADINO: Are you seeking from this Commission -- Are you seeking approval of your program, including action?

MR. HANAUER: Yes, sir, approval of the program.

For specific action, we will come back to the Commission. The rulemaking for most plants and any orders that would be proposed would come back to the Commission.

CHAIRMAN PALLADINO: So in approving this, we would not necessarily be approving the show cause?

MR. HANAUER: That is corr ct, or you could explicitly reserve it.

CHAIRMAN PALLADINO: Yes.

COMMISSIONER ROBERTS: I think if you approve the piece of paper you have, you are approving the show cause order.

CHAIRMAN PALLADINO: Unless we express it.

MR. DENTON: Perhaps you should approve it with the exception of treating Robinson in the same 50.55(f) category as proposed for the others.

CHAIRMAN PALLADINO: Yes.

COMMISSIONER ROBERTS: That would be my choice.

CHAIRMAN PALLADINO: We could live with that. We are going to have another session on this. Probably at that time, we will want to focus on the questins regarding rulemaking and some of the policy issues.

MR. DENTON: On the rulemaking, we won't be ready next week with the rule. We figure that if you agree with the rule, it will take us a while to put it together. We think that there is ample time for it.

CHAIRMAN PALLADINO: I was thinking of the details.

COMMISSIONER ASSELSTINE: But you are asking for Commission direction to prepare a rule, and come to us with it in six months.

MR. DENTON: That is right.

There is also a table in here, Table 35, that is a little bit clearer than the one that had the handwritten notes, and it shows the --

CHAIRMAN PALLADINO: What page is that?

MR. DENTON: Page 35.

CHAIRMAN PALLADINO: Page 35.

MR. DENTON: It shows the plants which will be within the screening criterion at the end of life which will, without any change, be between one and two times the screening criterion, which will be four times the screening criterion. It is just another way of portraying the same information that was on that page 16 that we mentioned.

CHAIRMAN PALLADINO: Okay, are there any other questions?

I thank you. That was a very enlightening and good presentation.

I want to take this opportunity to again express to Steve Hanauer our best wishes and our many thanks for his dedicated public service. Good luck to you in your new venture.

COMMISSIONER ASSELSTINE: I certainly join in that speech.

MR. HANAUER: Thank you, Mr. Chairman. It has been a privilege to serve the Commission in various ways. I will remember it with pleasure.

CHAIRMAN PALLADINO: We will stand adjourned.

(Whereupon, at 3:45 p.m., the meeting adjourned.)

NUCLEAR REGULATORY COMMISSION

This is to certify that the attached proceedings before the

COMMISSION MEETING

in the matter of: PUBLIC MEETING - BRIEFING ON PRESSURIZED THERMAL SHOCK

Date of Proceeding: December 1, 1982

Docket Number:

Place of Proceeding: Washington, D. C.

were held as herein appears, and that this is the original transcript thereof for the file of the Commission.

Patricia A. Minson

Official Reporter (Typed)

Patricia A. Minson

Official Reporter (Signature)

PRESSURIZED THERMAL SHOCK

PRESENTATION TO THE

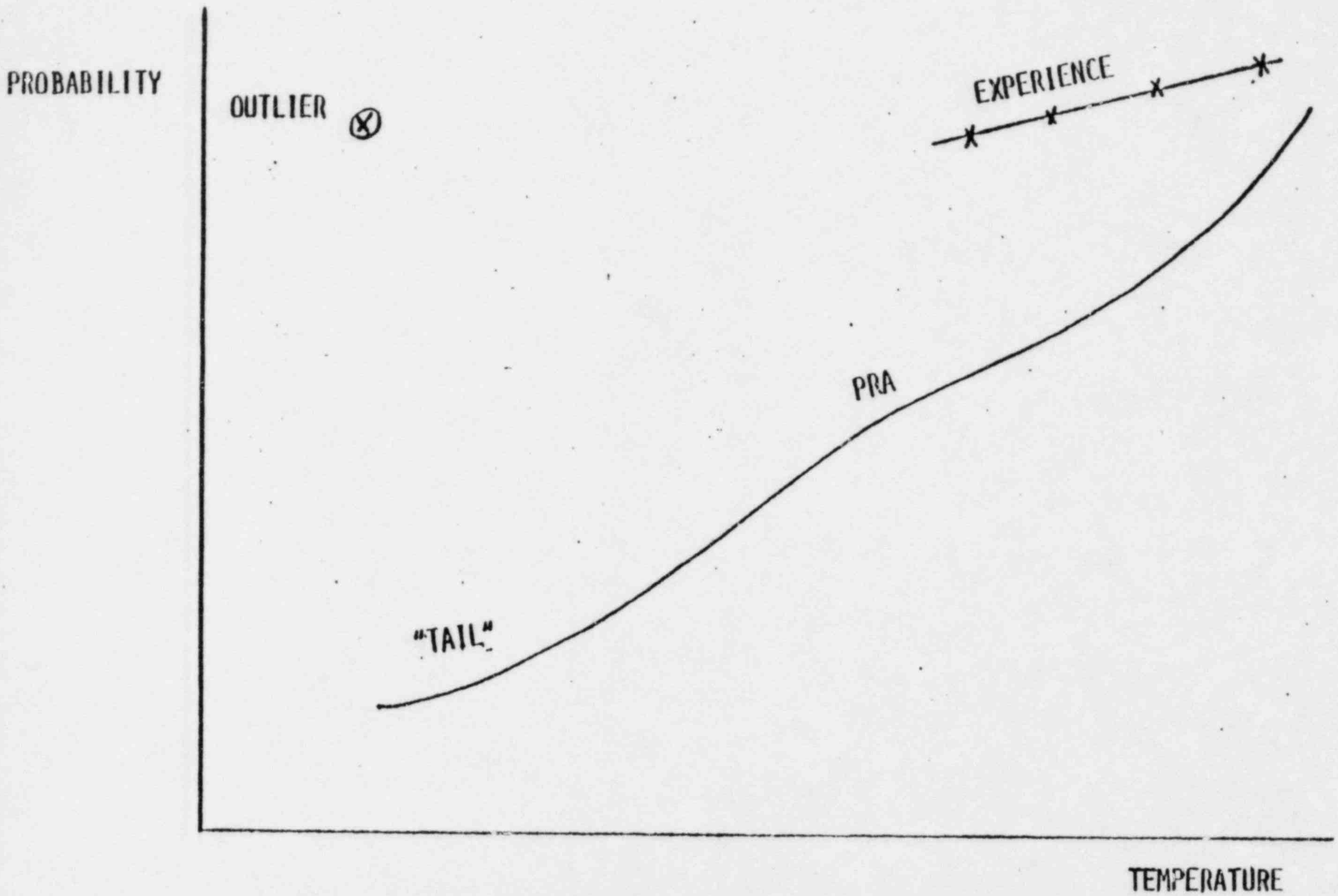
NUCLEAR REGULATORY COMMISSION

DECEMBER 1, 1982

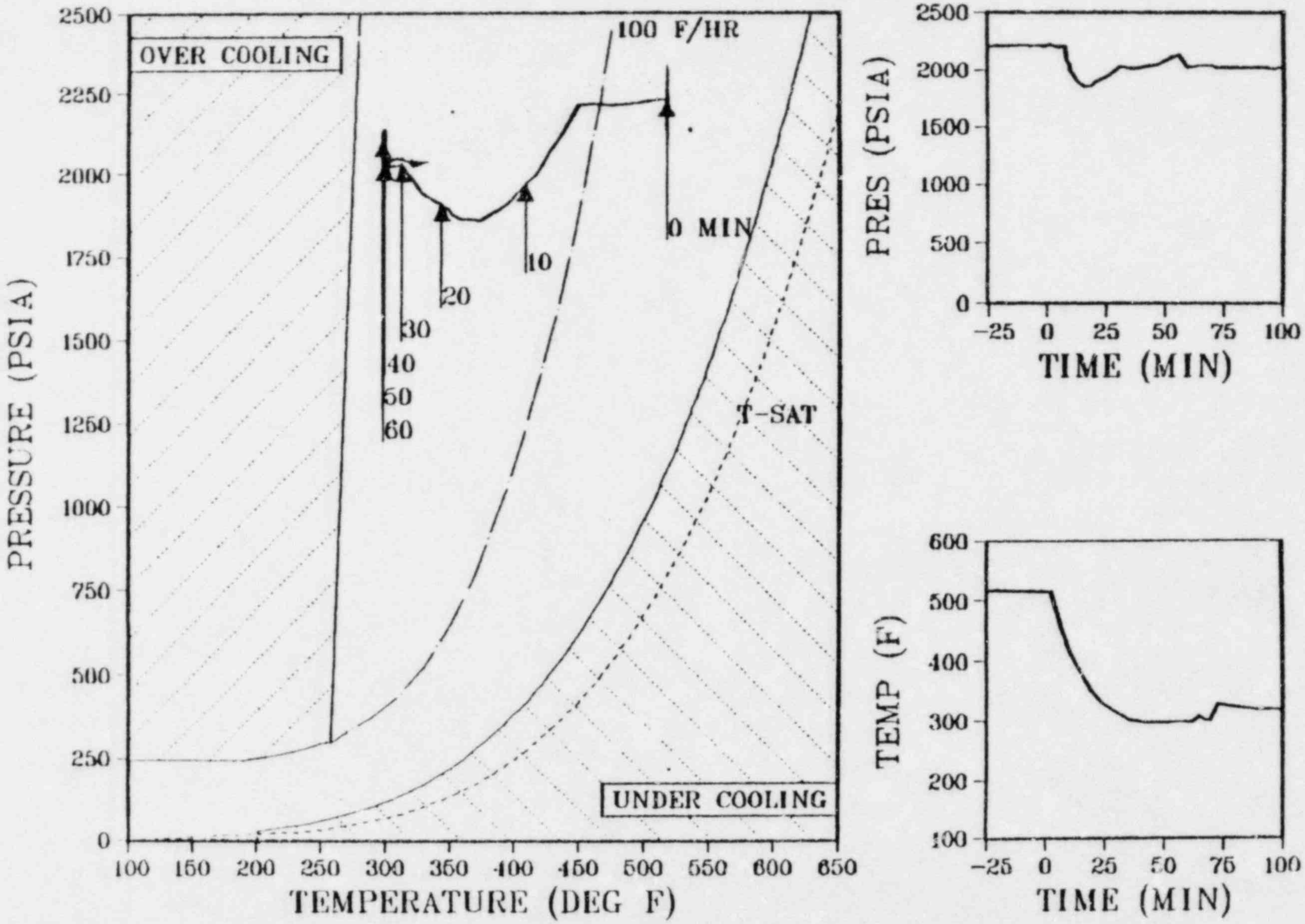
STEPHEN H. HANAUER

OUTLINE

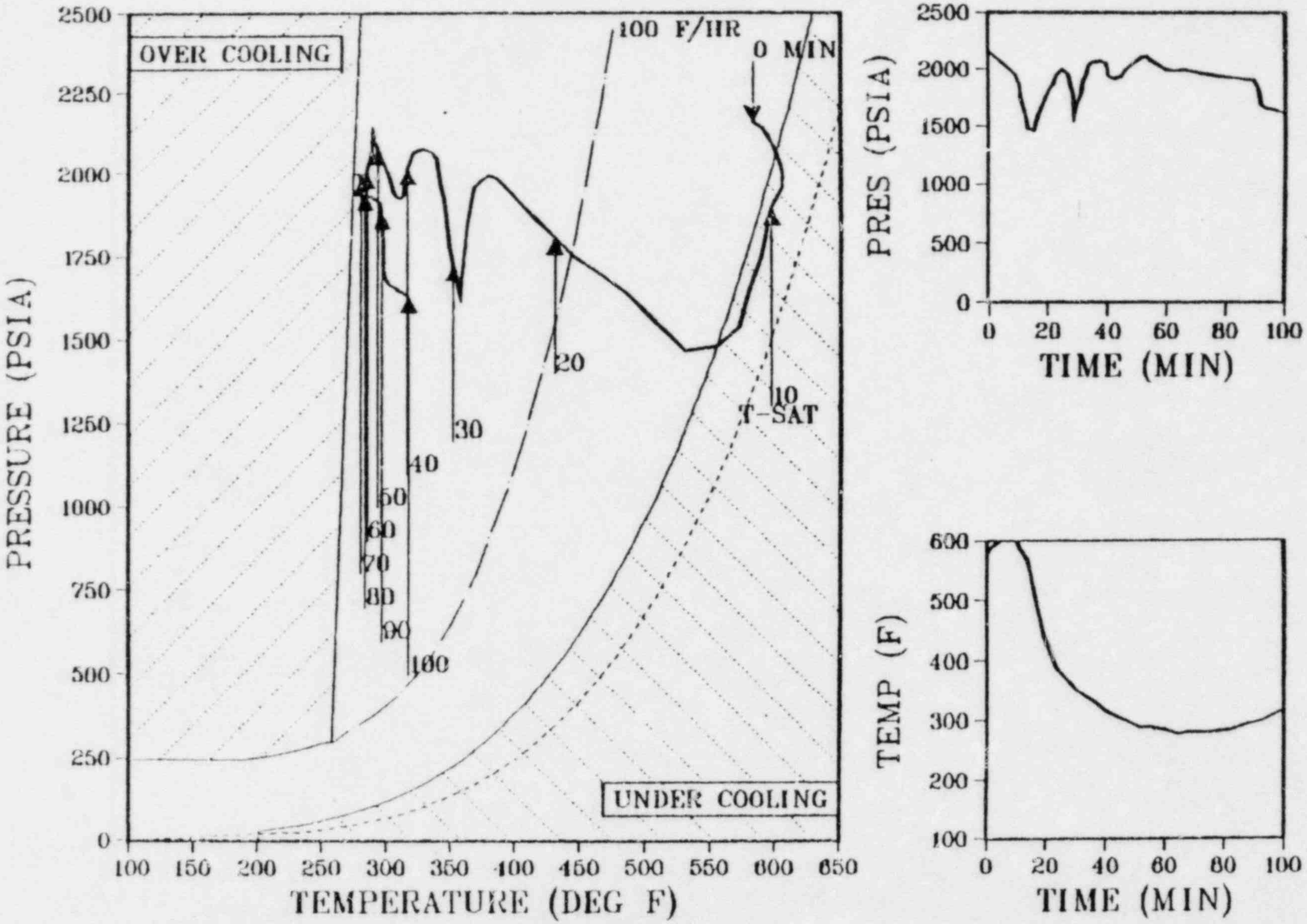
- o GENERAL APPROACH
- o EVALUATION OF EXPERIENCE
- o SCREENING CRITERION
- o APPLICATION TO PLANTS
- o PROBABILISTIC EVALUATION
- o CONCLUSIONS AND RECOMMENDATIONS


PROBABILITY
OUTLIER
EXPERIENCE
PRA
"TAIL"
TEMPERATURE

PRESSURE - TEMPERATURE DIAGRAM
EVENT: H.R. ROBINSON SLB 04/28/70

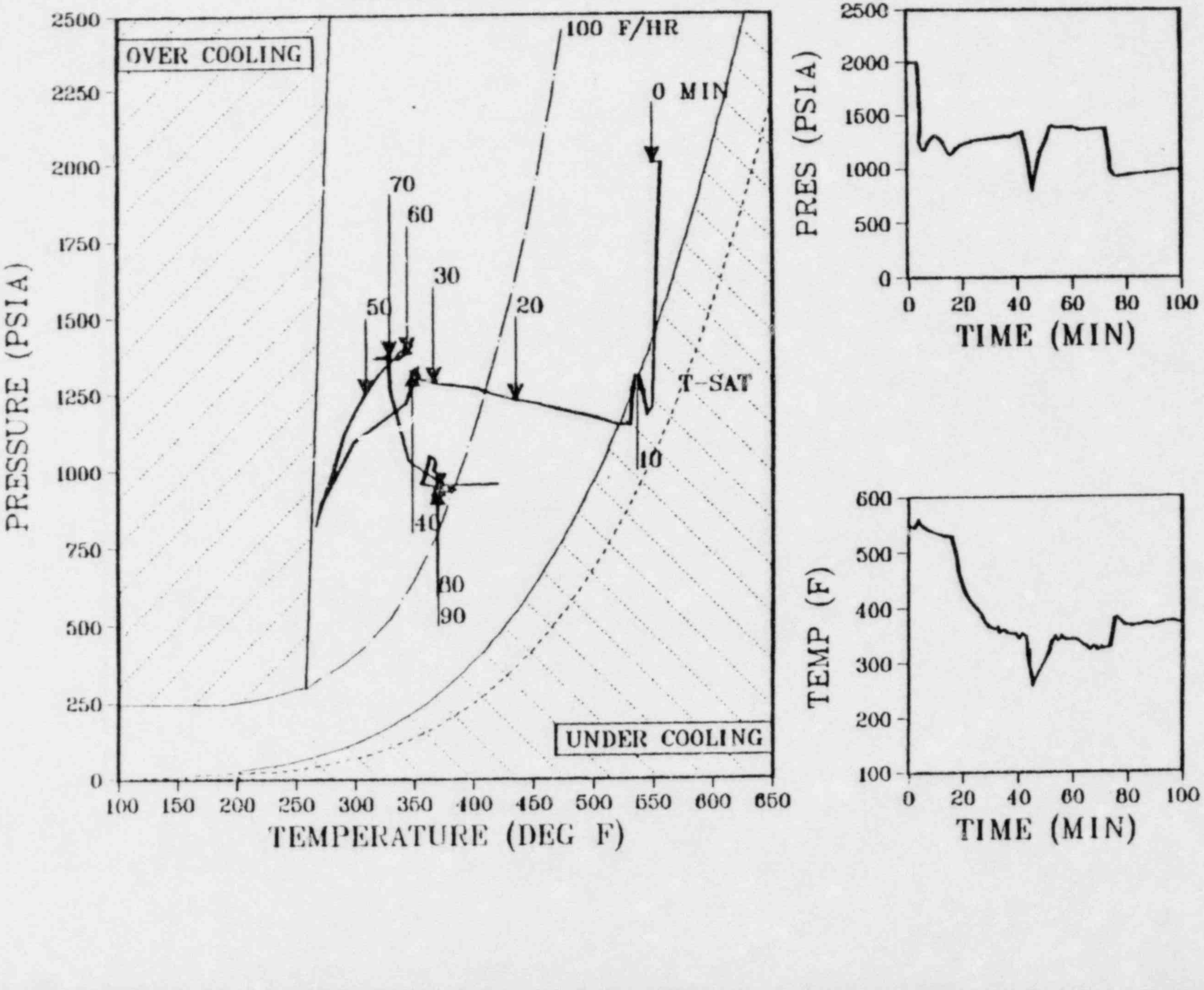


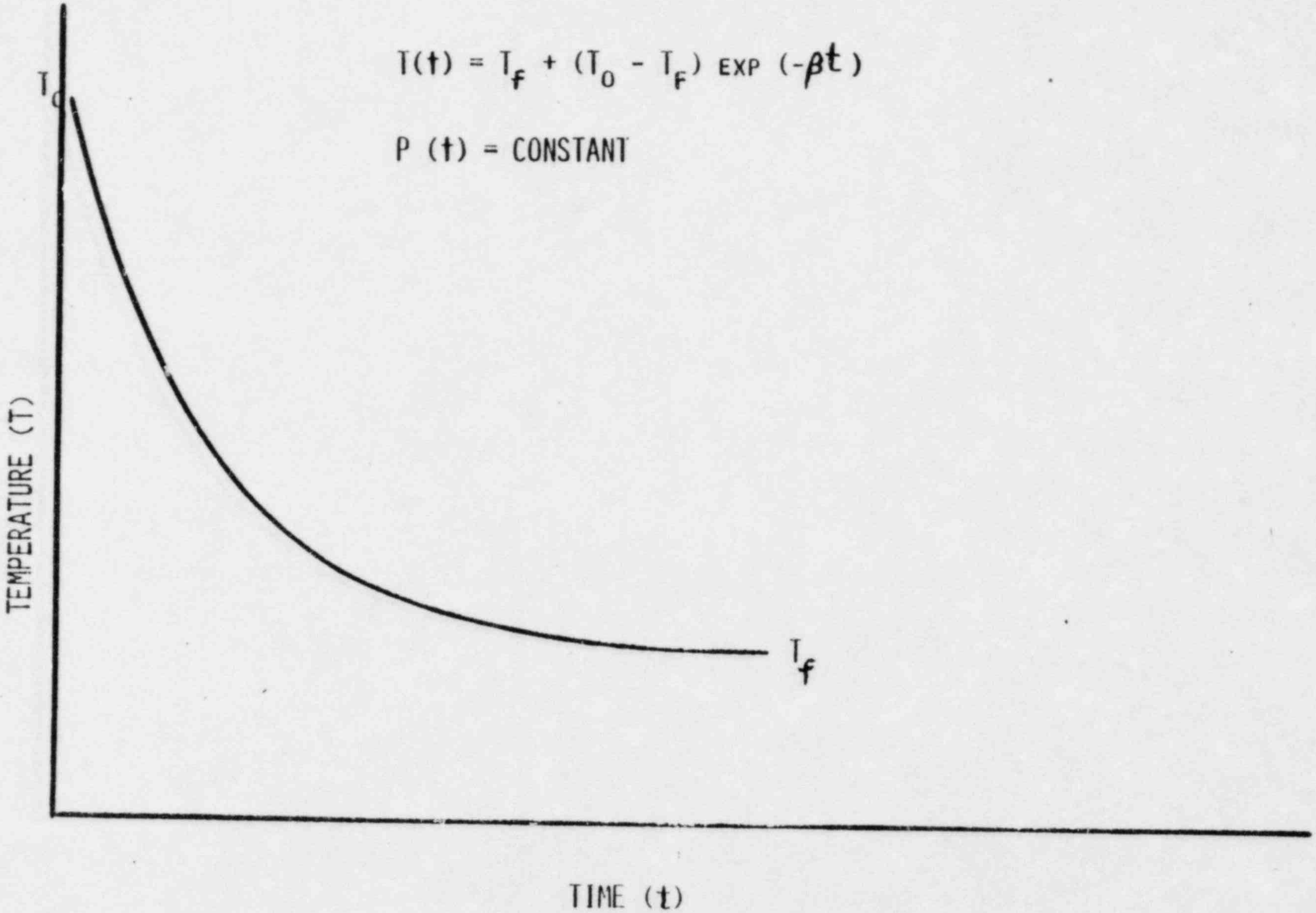
PRESSURE – TEMPERATURE DIAGRAM
EVENT: RANCHO SECO NNI/ICS 03/20/78

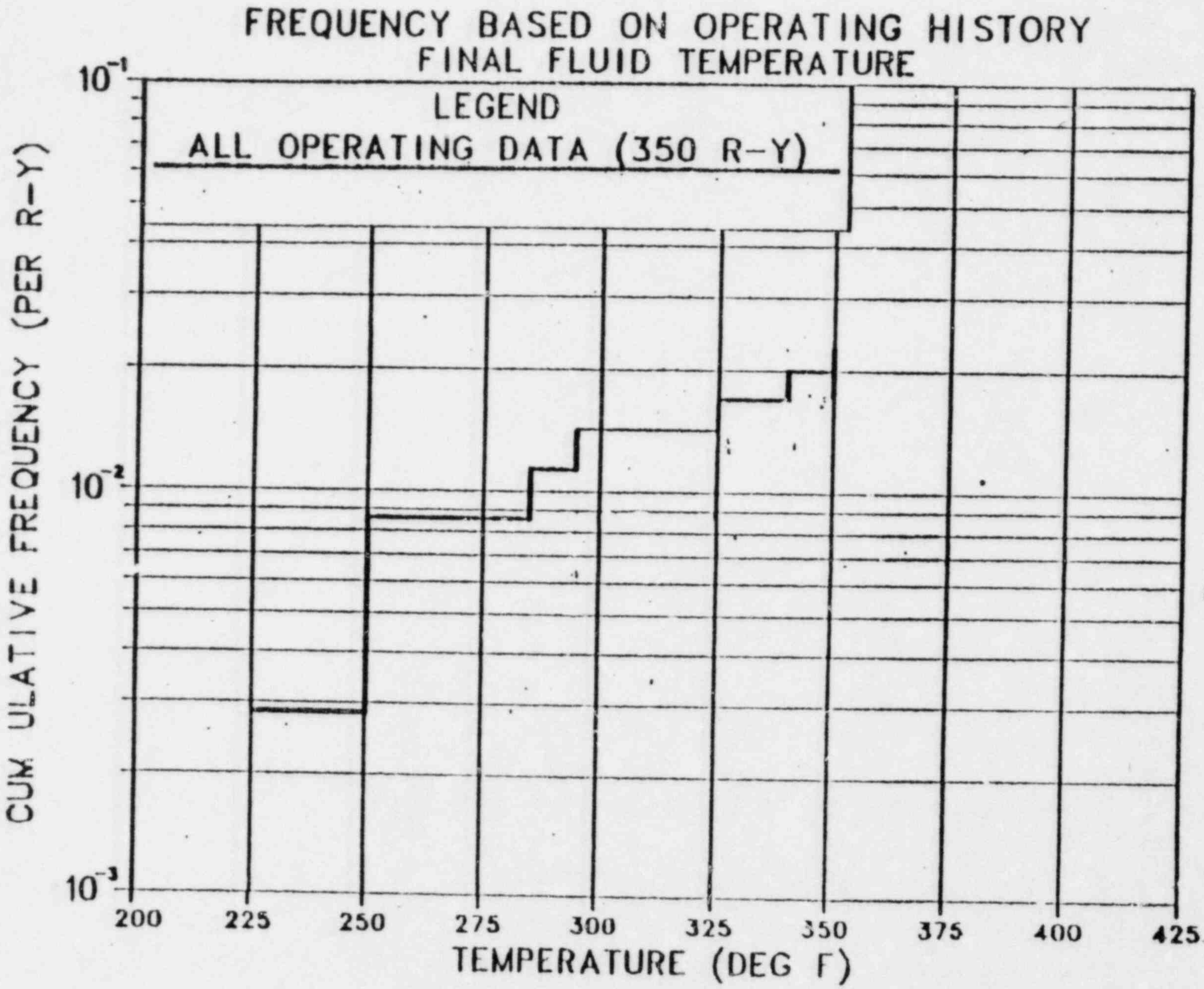


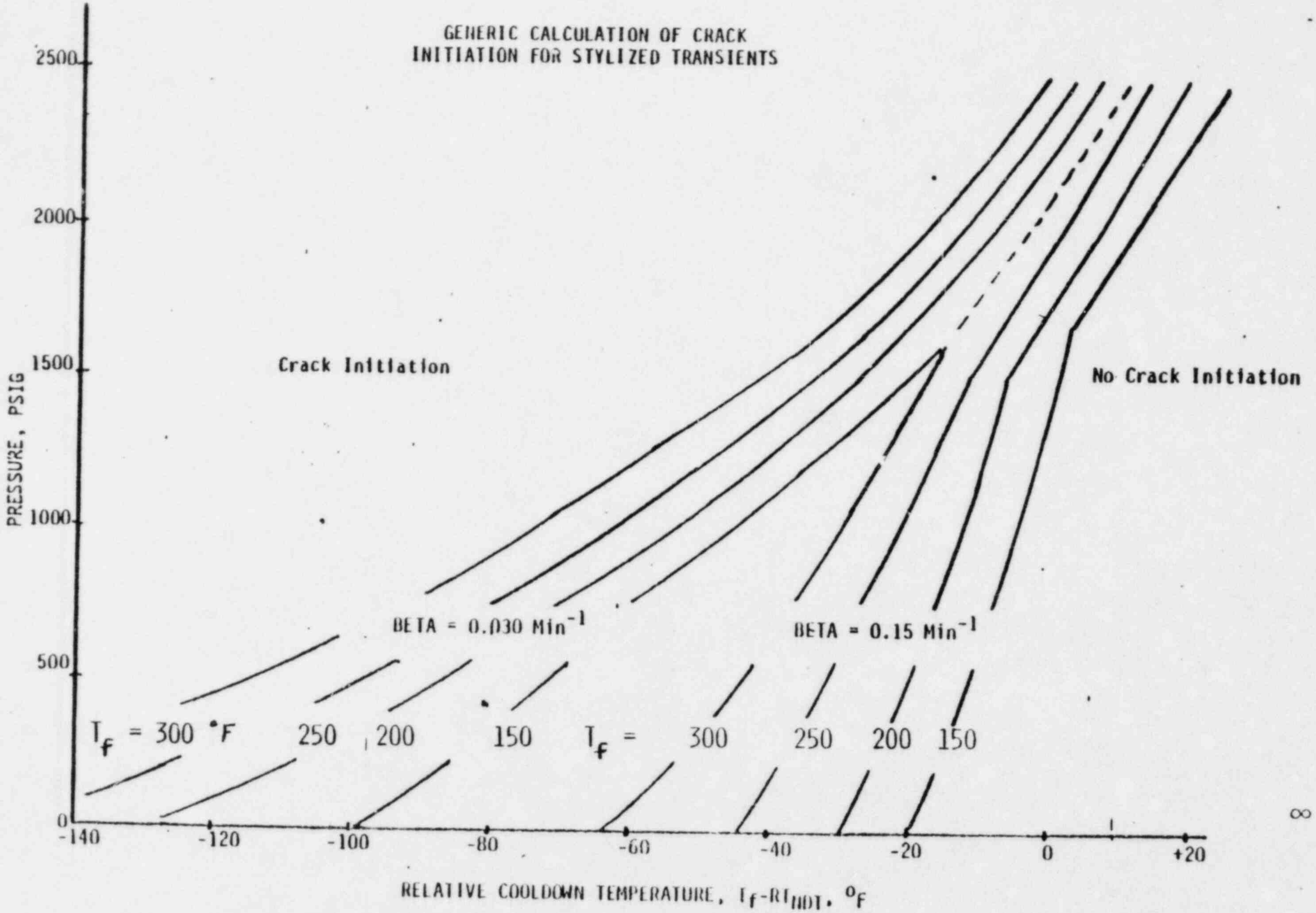
PRESSURE - TEMPERATURE DIAGRAM

EVENT: R.E. GINNA SGTR + PORV 01/25/82



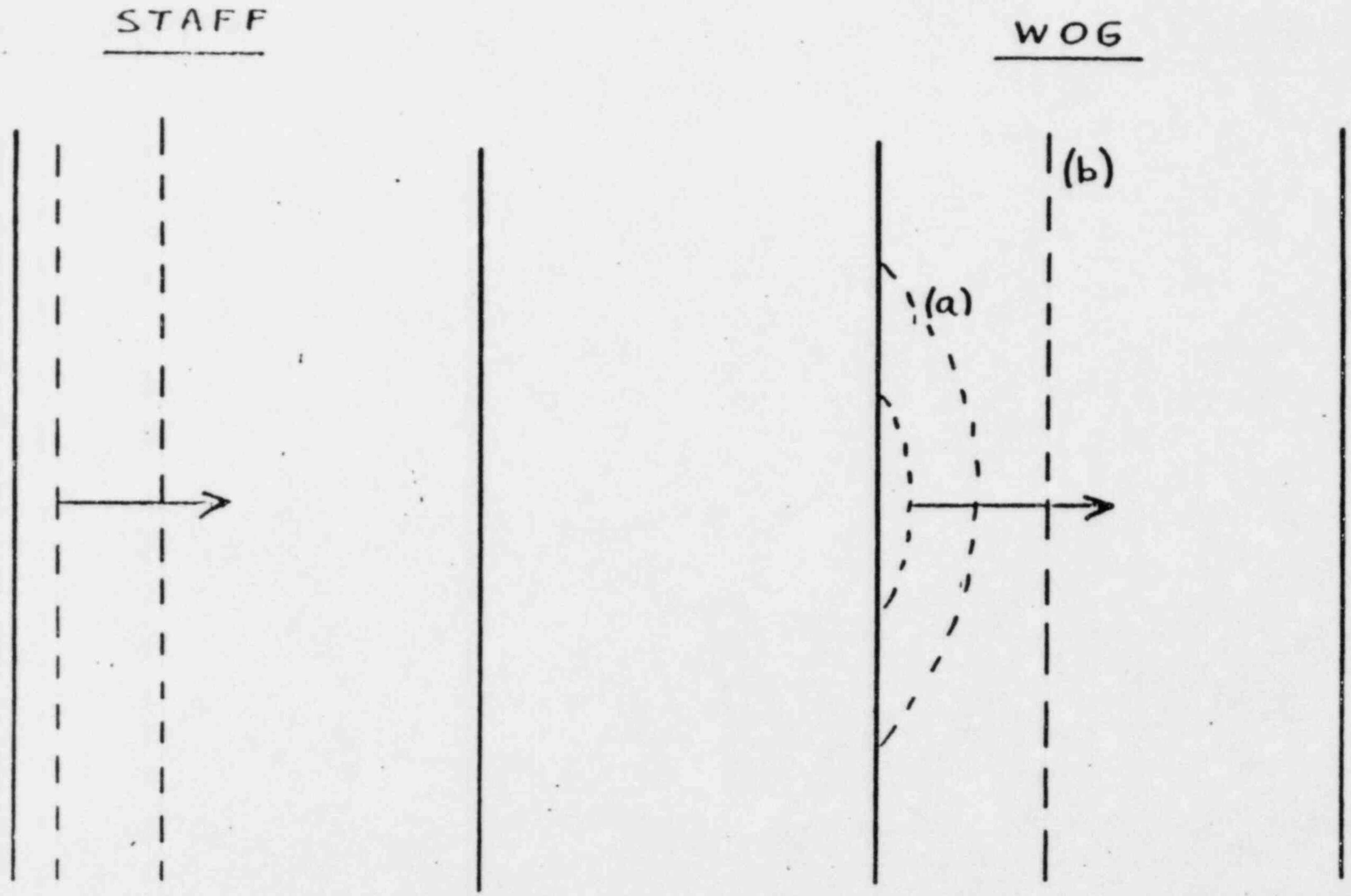

$T(t) = T_f + (T_0 - T_f) \, EXP \, (-\beta t)$
P (t) = CONSTANT
T_0
T_f
TEMPERATURE (T)
TIME (t)


FREQUENCY BASED ON OPERATING HISTORY
FINAL FLUID TEMPERATURE
LEGEND
ALL OPERATING DATA (350 R-Y)
CUMULATIVE FREQUENCY (PER R-Y)
10^{-1}
10^{-2}
10^{-3}
200
225
250
275
300
325
350
375
400
425
TEMPERATURE (DEG F)



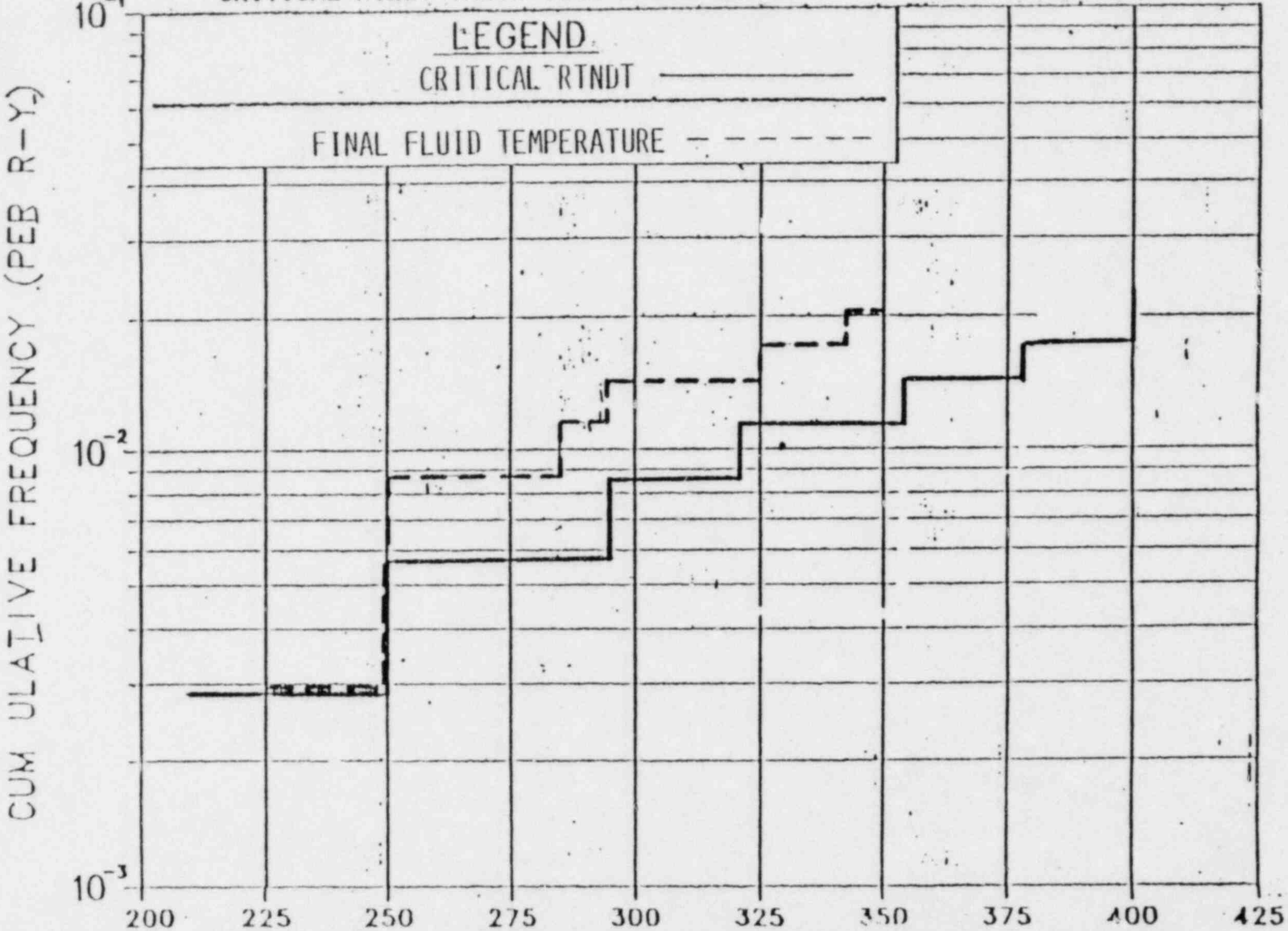
GENERIC CALCULATION OF CRACK
INITIATION FOR STYLIZED TRANSIENTS
2500
2000
1500
1000
500
0
PRESSURE, PSIG
Crack Initiation
No Crack Initiation
BETA = 0.030 Min^-1
BETA = 0.15 Min^-1
T_f = 300 °F
250
200
150
T_f =
300
250
200
150
-140
-120
-100
-80
-60
-40
-20
0
+20
RELATIVE COOLDOWN TEMPERATURE, T_f-RT_NDT, °F

ASSUMPTIONS ON FLAW AND CRACK GEOMETRY



FREQUENCY BASED ON OPERATING HISTORY

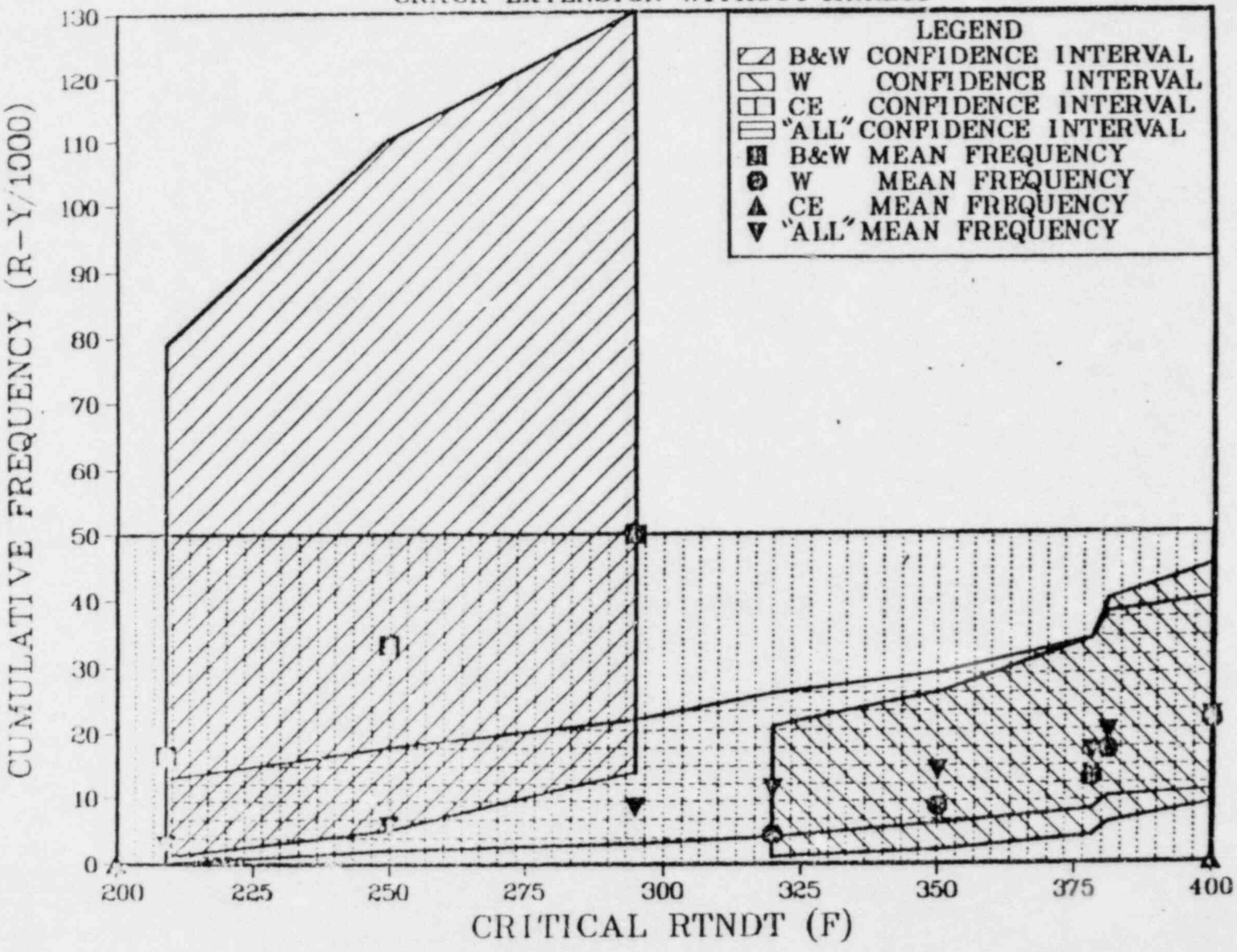
CRITICAL RTNDT VALUE (OCA RESULTS) AND FINAL FLUID TEMPERATURE



CRITICAL RTNDT VALUE (OCA RESULTS) OR FINAL FLUID TEMPERATURE

OPERATING EXPERIENCES (90% CONFIDENCE INTERVALS)

CRACK EXTENSION WITHOUT ARREST



SCREENING CRITERION

o LONGITUDINAL CRACK	270°F
o CIRCUMFERENTIAL CRACK	300°F

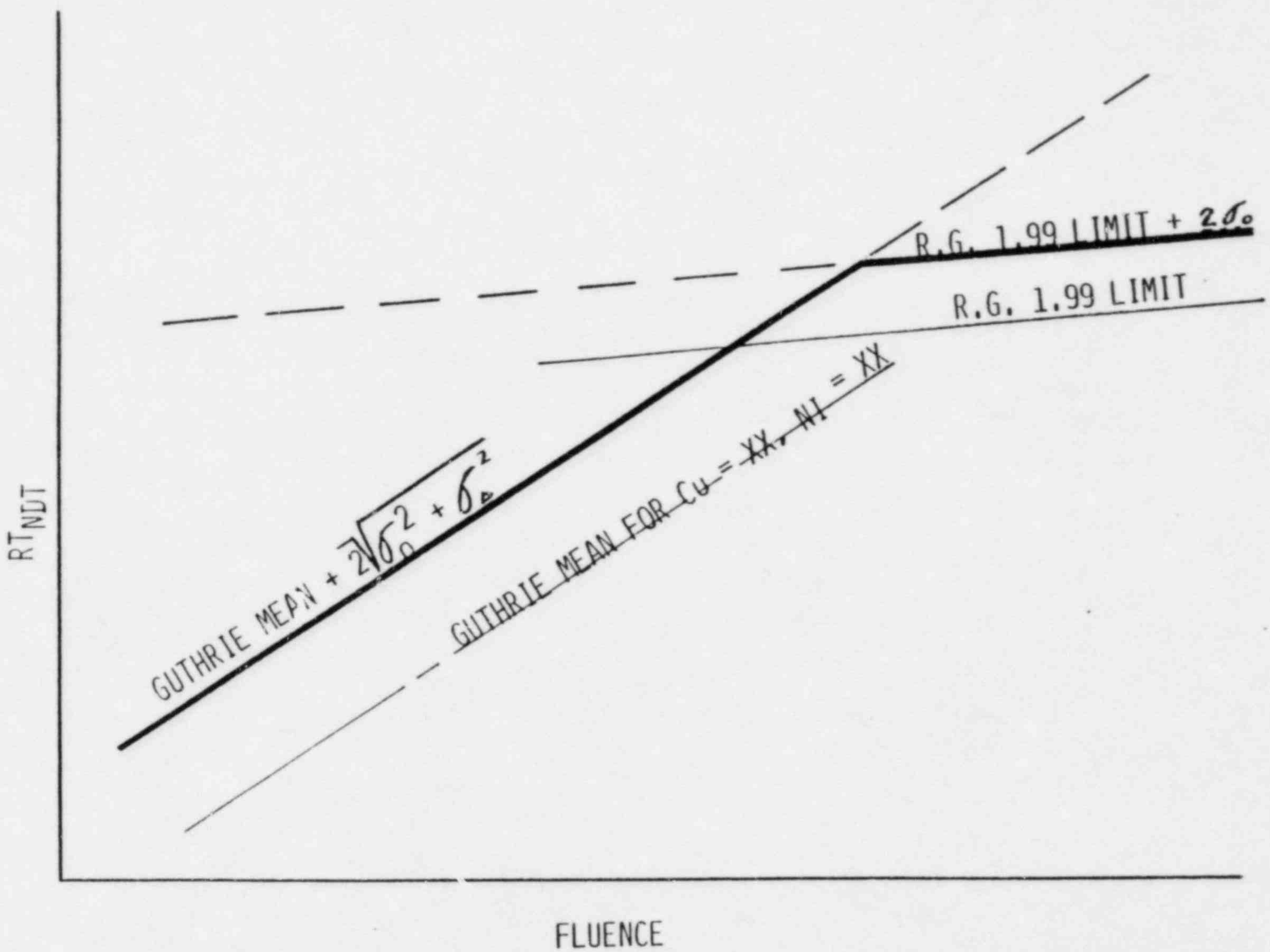
EVALUATING A SPECIFIC VESSEL

$$RT_{NDT} = RT_0 \quad \text{(BEST ESTIMATE)}$$

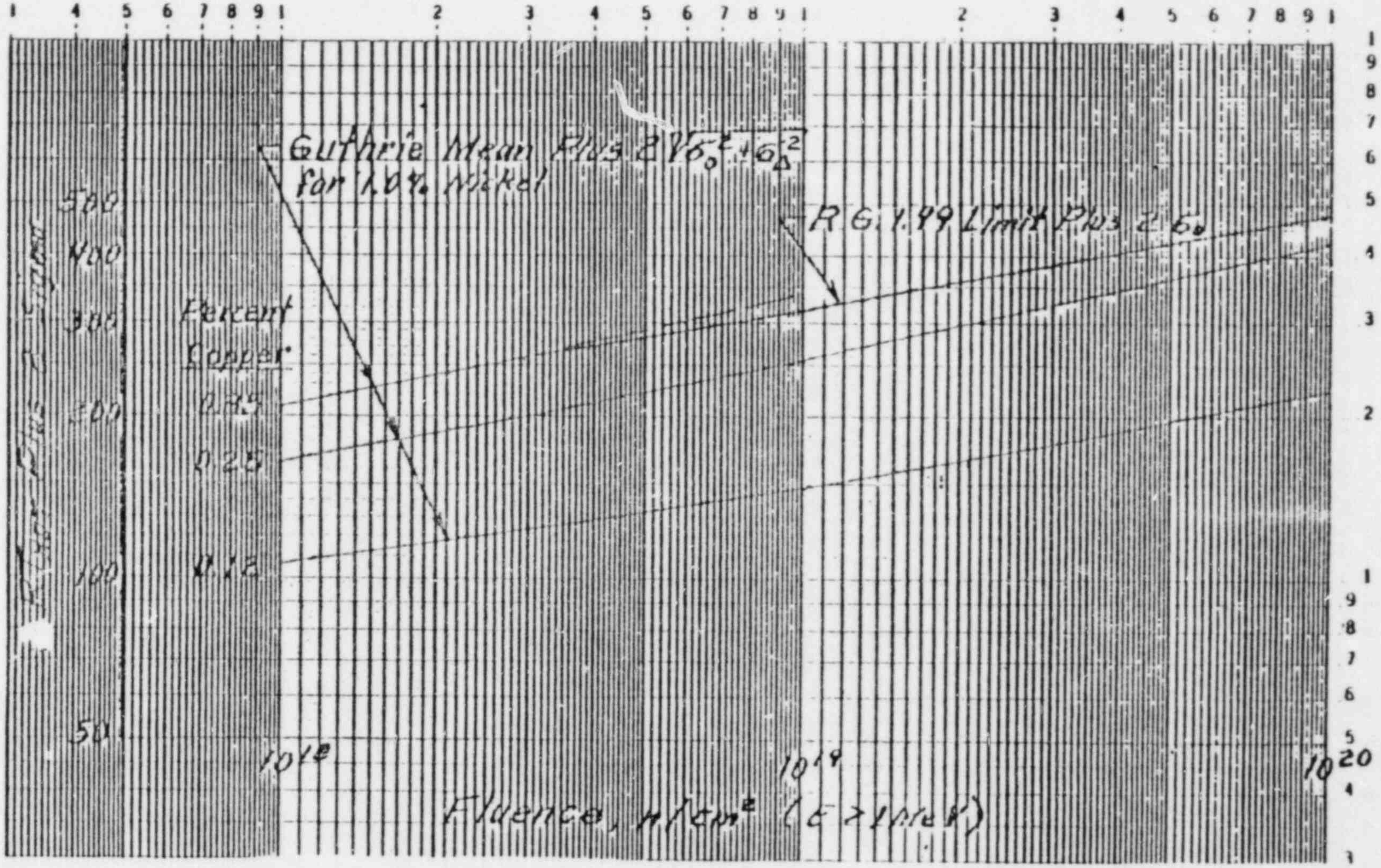
$$+ \Delta RT \quad \text{(BEST ESTIMATE - GUTHRIE)}$$

$$+ 2\sqrt{\sigma_0^2 + \sigma_\Delta^2}$$

LIMITED BY RG 1.99 + $2\sigma_0$



R.G. 1.99 LIMIT + 2σ₀
R.G. 1.99 LIMIT
GUTHRIE MEAN + 2$\sqrt{\sigma_0^2 + \sigma_\Delta^2}$
GUTHRIE MEAN FOR Cu = XX, Ni = XX
RT_{NDT}
FLUENCE



EXAMPLE OF NRC PRESCRIPTION FOR RT_{NDT} (FOR ASSUMED RT_{NDT} (o) OF $0^{o}F$)

Table P.1 RT_{NDT} Values for All Plants(1) Calculated Per the Recommendations of the Working Group on RT_{NDT} (2) for the Vessel Inside Surface.

Plant NSSS/Vessel Fabricators	EFPY as of 12/31/81	Fluence n/cm² ×10¹⁸	Copper %	Nickel %	Mean Initial RT_{NDT}	Mean ΔRT_{NDT}	$2\sqrt{\sigma_0^2+\sigma_\Delta^2}$ (5)	RT_{NDT}, °F, as of Dec 31, 1981(6) Circum.	Axial	Licensee's RT_{NDT}, °F	Year Exceed Screening RT
Robinson 2 W/CE	7.10	(14.1)(3)(8) 14.8 (3)(8)	(0.35) 0.27	(1.20) 0.20	(-56) -56	(303)(4) 151	34 (4) 59	281	 154	290 220	1988
Turkey Point 4 W/B&W	5.67 No Axial Welds	9.1 (9)	(0.32)	(0.57)	(0)	(200)	59	259		211	1989
Turkey Point 3 W/B&W	5.67 No Axial Welds	(9.1)(9)	(0.32)	(0.57)	(0)	(200)	59	259			1989
Fort Calhoun CE/CE	5.07	(7.04) 5.1 (10)	(0.35) 0.35	0.99 0.99	(-56) -56	(264)(4) 248 (4)	34(4) 34 (4)	242	 226	 209 (239)(7)	1990
Maine Yankee CE/CE	5.90	(5.02) 4.14	(0.36) 0.36	(0.99) 0.99	(-56) -56	(248)(4) 238(4)	34(4) 34(4)	226	 216	 170 (198)(7)	1995
Indian Point 3 W/CE	2.98 Plate Governs	(1.67)	(0.24) 0.24	(0.52) 0.52	(+74) +74	(90) 90	48 48	212	 212		
Yankee Rowe W/B&W/B&W	14.56 Plate Governs	(11.35)	(0.20) 0.20	(0.63) 0.63	(+30) +30	(133) 133	48 48	211	 211		
Rancho Seco B&W/B&W	3.54	(2.33) 2.05	(0.31) 0.35	(0.59) 0.59	(0) 0	(135) 148	59 59	194	 207		1993
Three Mile Island 1 B&W/B&W	3.52	(1.87) (1.87)	(0.31) 0.35	(0.68) 0.60	(0) 0	(133) 145	59 59	192	 204	 145	1995
Oconee 2 B&W/B&W	4.71 No Axial Welds	(2.87)	(0.35)	(0.71)	(0)	(172)	59	231			1996

(1) See footnote(s), last page of table.

These values are subject to change when plant-specific analyses yield better information.

Table P-1 (Continued)

Plant NSSS/Vessel Fabricators	LFPY as of 12/31/81	Fluence n/cm^2 $\times 10^{18}$	Copper %	Nickel %	Mean Initial RT_{NDT}	Mean ΔRT_{NDT}	$2\sqrt{\sigma_0^2+\sigma_\Delta^2}$ (5)	RT_{NDT}, °F, as of Dec 31, 1981(6) Circum.	Axial	Licensee's RT_{NDT}, °F	Year Exceed Screening RT
Point Beach 1	8.07	(10.01)	(0.24)	(0.57)	(0)	(151)	59	210			
W/B&W		7.34	0.24	0.57	0	139	59		198		
Oconee 1	5.04	(2.32)	(0.26)	(0.61)	(0)	(113)	59	172			
B&W/B&W		2.73	0.31	0.55	0	138	59		197	160	
Zion 1	4.97	(3.13)	(0.35)	(0.59)	(0)	(166)	59	225			
		0.99	0.31	0.61	0	108	59		167		2000
Indian Point 2	4.40	No Circum Data									
W/CE		2.2	0.34	1.2	-56	211 (4)	34 (4)		189		
Arkansas ANO-1	4.42	(2.70)	(0.31)	(0.59)	(0)	(140)	59	199			
B&W/B&W		1.99	0.31	0.59	0	129	59		188		
Point Beach 2	7.54	(9.35)	(0.25)	(0.59)	(0)	(156)	59	215			
W/B&W, CE		No Axial Welds									
Ginna	8.18	(9.49)	(0.25)	(0.56)	(0)	(154)	59	213			
W/B&W		No Axial Welds									
San Onofre	9.04	(33.45)	(0.27)	(0.20)	(-56)	(188)	59	191		233	
W/CE		27.12	0.27	0.20	-56	178	59		181		
Zion 2	4.49	(2.83)	(0.26)	(0.61)	(0)	(119)	59	178			
W/B&W		0.90	0.35	0.59	0	118	59		177		
Palisades	4.12	(4.78)	(0.25)	(1.2)	(-56)	(174)	59	177			
CE/CE		4.78	0.25	1.2	-56	174	59		177		
Crystal River 3	2.48	(1.44)	(0.35)	(0.59)	(0)	(134)	59	193			
B&W/B&W		1.36	0.31	0.61	0	118	59		177		

Table P-1 (Continued)

Plant NSSS/Vessel Fabricators	EFPY as of 12/31/81	Fluence n/cm² x10¹⁸	Copper %	Nickel %	Mean Initial RT_{NDT}	Mean ΔRT_{NDT}	$2\sqrt{\sigma_0^2+\sigma_\Delta^2}$ (5)	RT_{NDT}, °F, as of Dec 31, 1981(6) Circum.	Axial	Licensee's RT_{NDT}, °F
Surry 1	4.88	(7.61)	(0.25)	(0.51)	(0)	(141)	59	200		
W/B&W		1.66	0.21	0.59	0	81	59		140	
Cook 1	4.56	(2.87)	(0.40)	(0.82)	(-56)	(222) (4)	34(4)	200		
W/CE		1.55	0.13	0.99	-56	58	59		61	
North Anna 1	2.41	(4.42)	(0.14)	(0.80)	(+38)	(76)	48	162		
W/RD		No Axial Welds		Forging Governs		48			162	
Beaver Valley	1.87	(3.16)	(0.37)	(0.62)	(-56)	(179)	59	182		
W/CE		0.47	0.36	0.62	-56	104	59		107	
North Anna 2	0.77	(1.38)	(0.13)	(0.83)	(+56)	(52)	48	156		
W/RD		No Axial Welds		Forging Governs		52	48		156	
Salem 1	2.26	(1.49)	(0.24)	(0.51)	(+5[illegible])	(87)	48	150		
W/CE			0.24	0.51	Plate Governs	87	48		150	
Oconee 3	4.78	(2.92)	(0.24)	(0.63)	(0)	(112)	59	(171)		
B&W/B&W		No Axial Welds								
Surry 2	4.83	(7.54)	(0.19)	(0.56)	(0)	(108)	59	167		
W/B&W, RD		1.64	0.21	0.59	0	81	59		140	
Calvert Cliffs 1	4.65	(6.84)	(0.30)	(0.18)	(-56)	(135)	59	138		
CE/CE		6.84	0.21(11)	0.85	-56	136	59		139	205(244)(7)
St. Lucie	3.52	(2.22)	(0.31)	(0.11)	(-56)	(98)	59	101		
CE/CE		2.22	0.30	0.64	-56	132	59		135	

Table P-1 (Continued)

Plant NSSS/Vessel Fabricators	EFPY as of 12/31/81	Fluence n/cm² x10¹⁸	Copper %	Nickel %	Mean Initial RT_{NDT}	Mean ΔRT_{NDT}	$2\sqrt{\sigma_0^2+\sigma_\Delta^2}$ (5)	RT_{NDT}, °F, as of Dec 31, 1981(6) Circum.	Axial	Licensee's RT_{NDT}, °F
Calvert Cliffs 2 CE/CE	3.63	(5.34)	(0.30) 0.30	(0.18) 0.18	(-56) -56	(127) 127	59 59	130	130	
Trojan W CBI	3.00	(2.07)	(0.16)	(0.62) Plate Governs	(+10)	(65) 65	48 48	123	123	
Davis Besse 1 B&W/B&W	1.68	(1.11) No Axial Welds	(0.24)	(0.61)	(0)	(85)	59	144		
Haddam Neck W/CE	10.92	(14.30) 11.90	(0.22) 0.22	(0.10) 0.10	(-56) -56	(111) 106	59 59	114	109	
Kewaunee W/CE	5.87	(7.86) No Axial Welds	(0.20)	(0.77)	(-56)	(129)	59	132		
Farley 1 W/CE	2.19	(3.70) 0.83	(0.24) 0.27	(0.60) 0.60	(-56) -56	(117) 89	59 59	120	92	
Millstone 2	3.91	(2.19) No Data for Axial Welds	(0.37)	(0.06)	(-56)	(114)	59	117		
Prairie Island 2 W/SFAC	5.62	(7.53) No Axial Welds	(0.19)	(0.13)	(-56)	(81)	59	84		
Prairie Island 1 W/SFAC	5.90	(7.90) No Axial Welds	(0.14)	(0.17)	(-56)	(60)	59	63		

Footnotes

(1) Arranged in descending order of the RT_{NDT} as of December 31, 1981 considering circumferential to be 30°F less severe than axial orientations.

(2) Memorandum, M. Vagins to S. Hanauer, August 30, 1982.

(3) Values shown in parentheses on top line are for circumferential welds, bottom line is for axial welds. When plate governs--both lines.

(4) Determined by Reg. Guide 1.99, Rev. 1, Upper Limit Line, $\sigma_\Delta = 0$.

(5) σ_o (17°F) and σ_Δ (24°F) are the standard deviations of the initial RT_{NDT} and ΔRT_{NDT}, respectively. If plate or forging governed, actual initial RT_{NDT} was available and $\sigma_o = 0$

(6) The sum of the Mean Initial RT_{NDT}, the mean ΔRT_{NDT} and $2\sqrt{\sigma_o^2+\sigma_\Delta^2}$, as of Dec. 31, 1981.

(7) Initial RT_{NDT} assumed by licensee to be -50°F and by CE to be -20°F. Values in parentheses are by CE.

(8) Fluence is per letter from CP&L Co., Sept. 24, 1982.

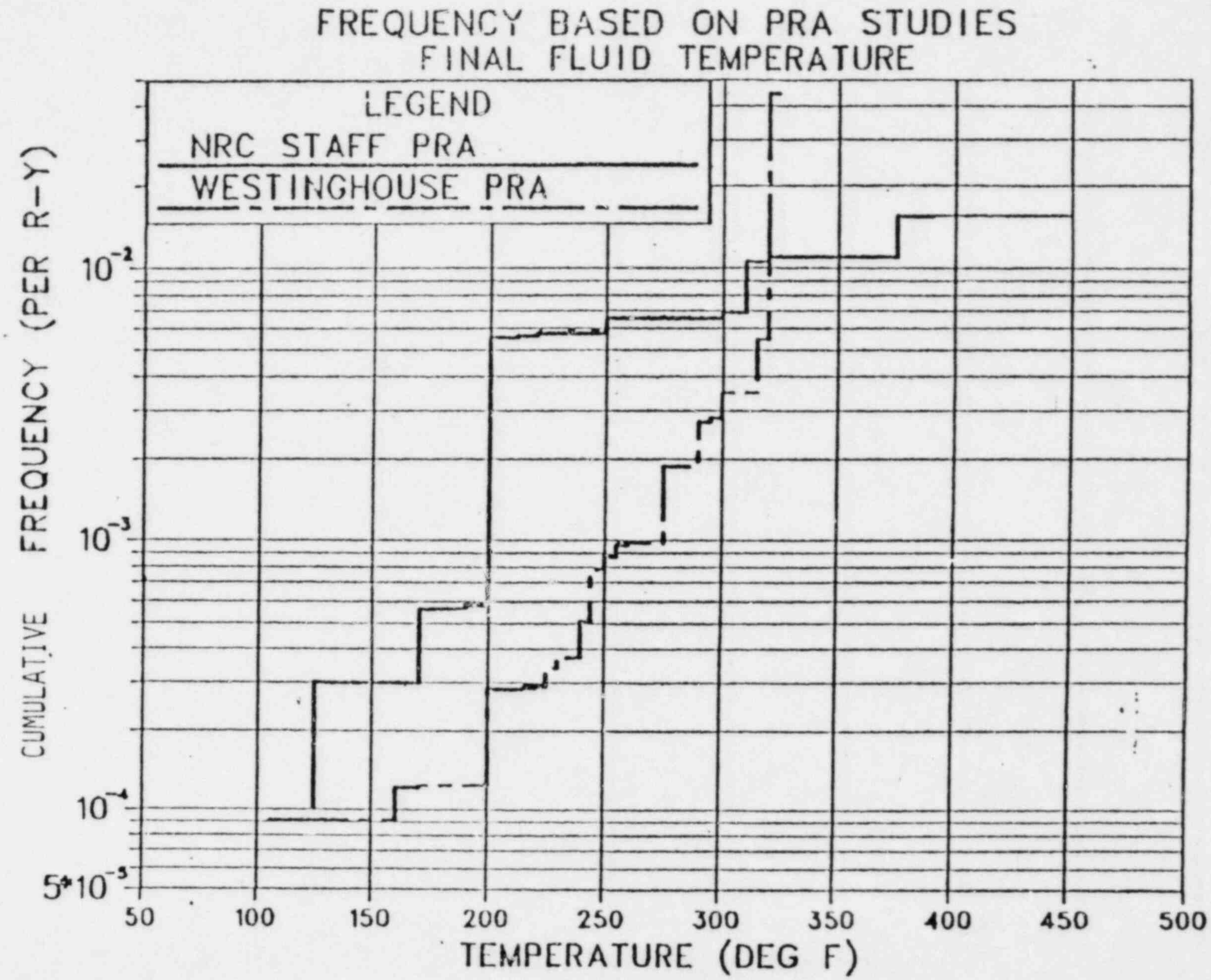
(9) Fluence reduced from 11.16 n/cm² per letter from FPL Aug. 31, 1982, on TP 4. TP 3 tentatively assumed to be the same as TP 4.

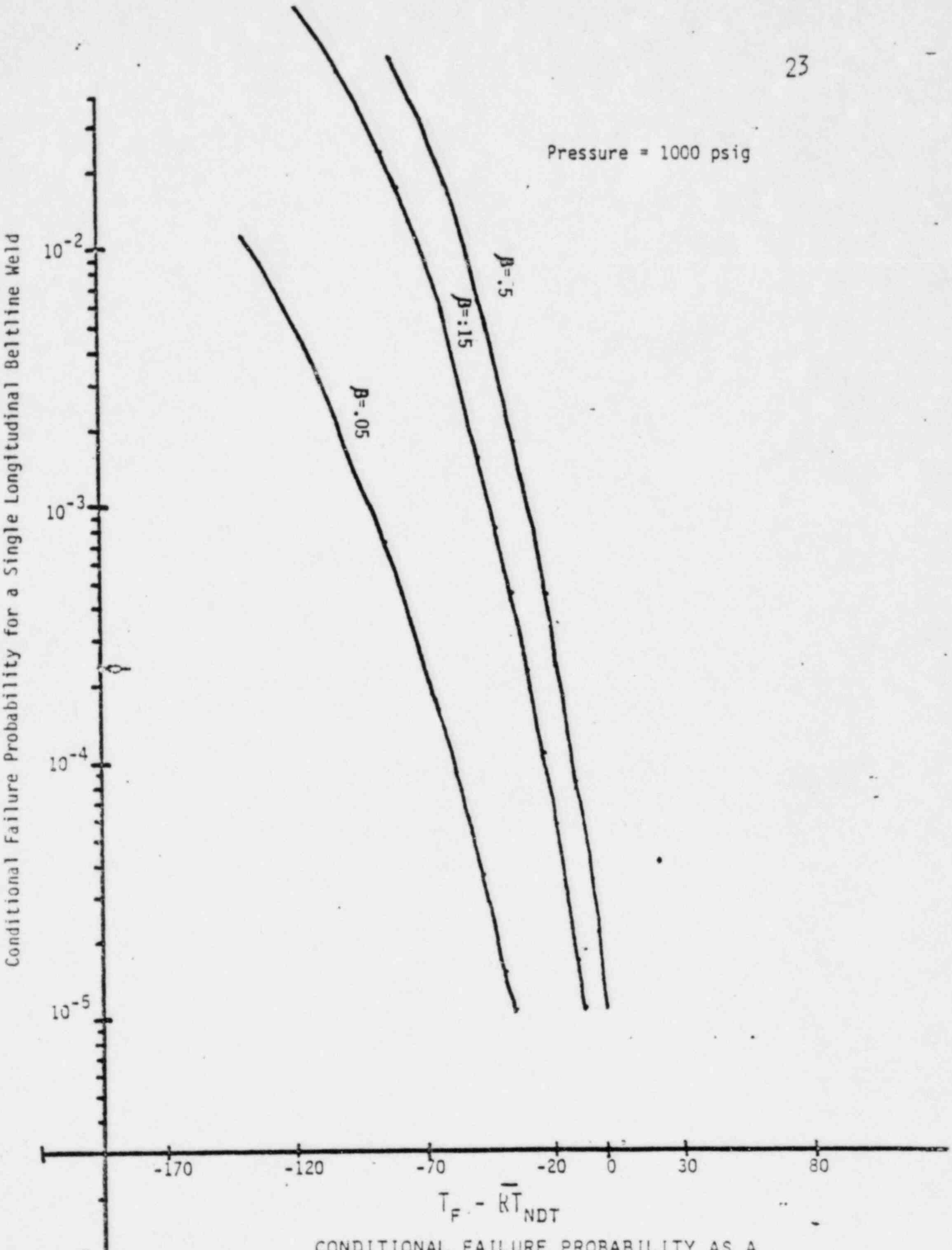
(10) Fluence reduced to 0.73 x peak per letter from Omaha PPD, Sept. 1, 1982.

(11) Cooper and Nickel values reduced per letter from Baltimore G&E, Oct. 28, 1982.

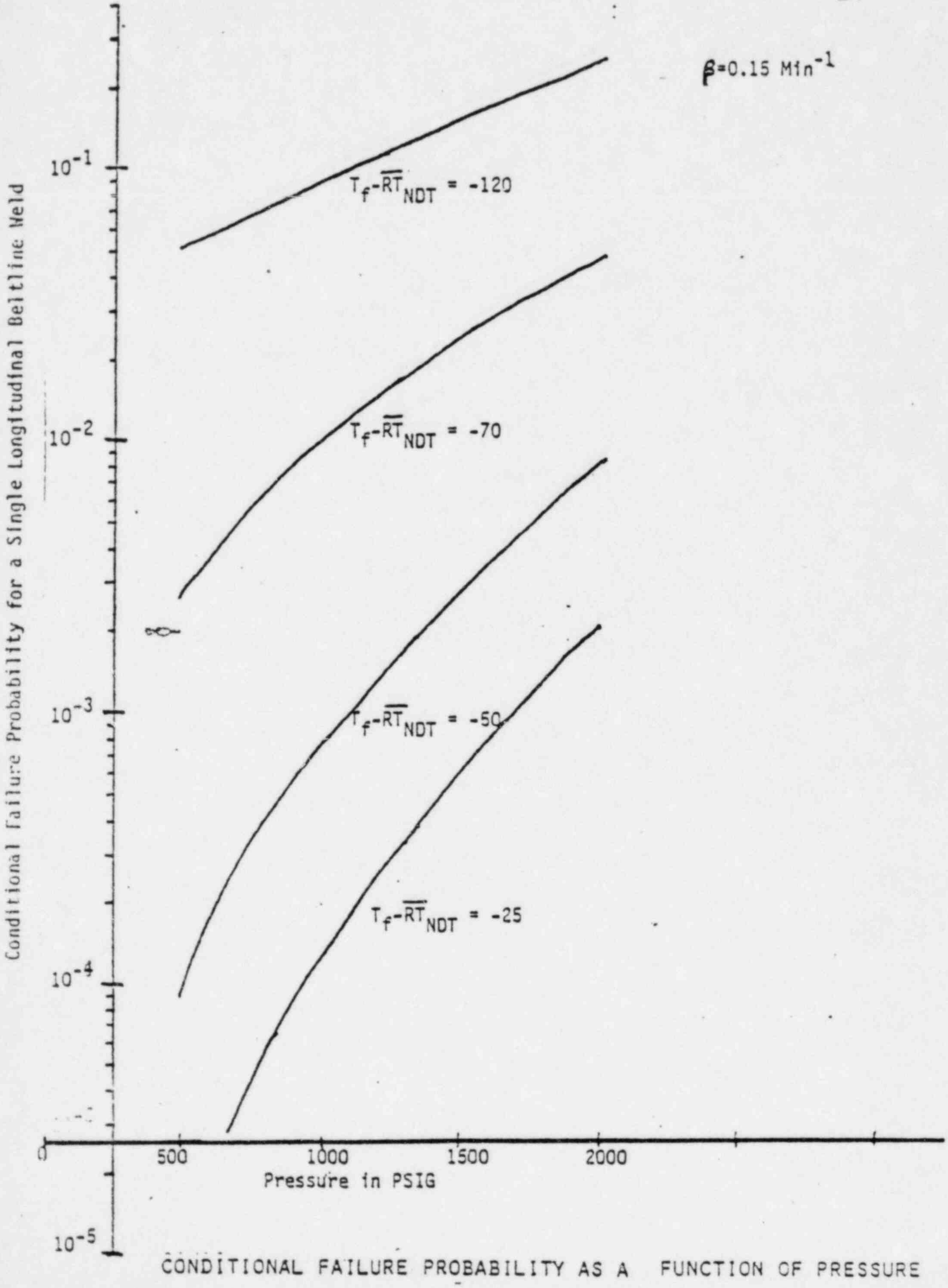
SIGNIFICANT PTS EVENT SEQUENCES

- SECONDARY (STEAM SIDE) DEPRESSURIZATION
- MAIN STEAM LINE BREAK
- SMALL STEAM LINE BREAK (OR STUCK OPEN STEAM GENERATOR SAFETY/RELIEF VALVE)
- SMALL BREAK LOSS-OF-COOLANT ACCIDENT
- STEAM GENERATOR TUBE RUPTURE


FREQUENCY BASED ON PRA STUDIES
FINAL FLUID TEMPERATURE
LEGEND
NRC STAFF PRA
WESTINGHOUSE PRA
CUMULATIVE FREQUENCY (PER R-Y)
10^-2
10^-3
10^-4
5*10^-5
50
100
150
200
250
300
350
400
450
500
TEMPERATURE (DEG F)

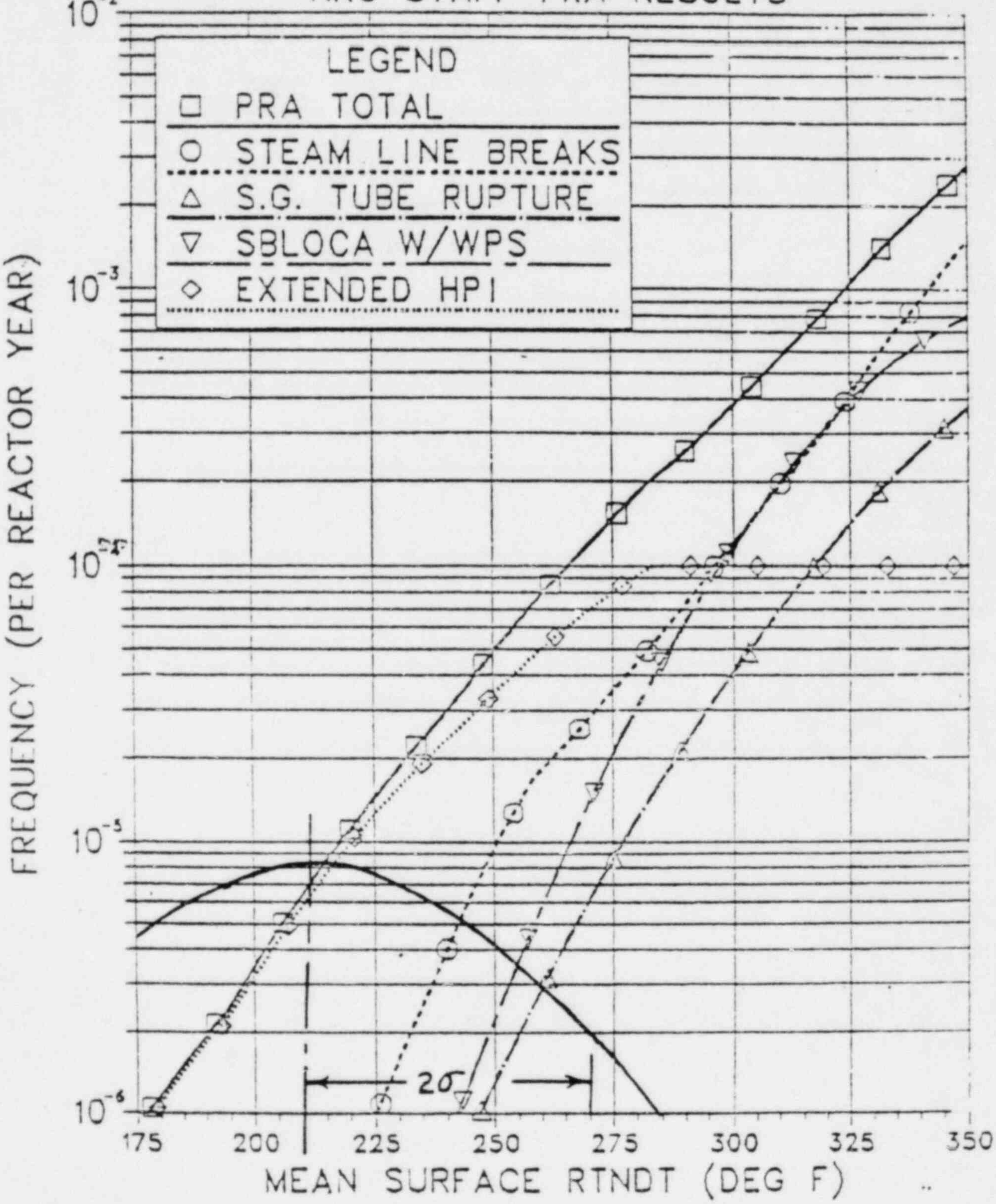


CONDITIONAL FAILURE PROBABILITY AS A FUNCTION OF T_F - MEAN VALUE OF RT_{NDT}



CONDITIONAL FAILURE PROBABILITY AS A FUNCTION OF PRESSURE

LONGITUDINAL CRACK EXTENSION NO ARREST
NRC STAFF PRA RESULTS



SAFETY GOAL

F	VESSEL CRACK
X	CORE MELT IF VESSEL CRACKS
Y	SIGNIFICANT EARLY RELEASE IF CORE MELTS
D	RISK OF EARLY DEATHS (EFFECTS OF DISPERSION, WIND DIRECTION, ETC.)

<u>CORE MELT</u> $XF \leq 10^{-5}$

<u>RISK</u> $XFYD \leq 5 \times 10^{-8}$

UNCERTAINTIES

- OPERATING EXPERIENCE
- OPERATION ACTIONS
- FLAWS AND CRACKS
- STRESSES
- MATERIAL PROPERTIES
- FRACTURE MECHANICS
- PROBABILISTIC CALCULATIONS

CONCLUSIONS

- IF RT_{NDT} < SCREENING CRITERION, PTS RISK IS ACCEPTABLE
  - NO VESSEL WILL EXCEED CRITERION FOR FEW YEARS
  - THERFORE NO NEED FOR IMMEIDATE SHUTDOWN OR ANNEALING
- MOST PLANTS CAN STAY BELOW CRITERION FOR FULL LIFE BY PRACTICABLE FLUX REDUCTION PROGRAMS
  - SUCH PROGRAMS SHOULD BE IMPLEMENTED TO AVOID FORECLOSURE OF THIS OPTION
- PLANTS PREDICTED TO EXCEED CRITERION SHOULD SUBMIT PLANT-SPECIFIC EVALUATIONS
- STAFF SHOULD DEVELOP DETAILED GUIDANCE FOR PLANT-SPECIFIC EVALUATIONS
- STAFF SHOULD CONSIDER CHANGES TO SOME REGULATIONS

RECOMMENDATIONS

- o PROPOSED RULEMAKING
  - ESTABLISH RT_{NDT} SCREENING CRITERION
  - PRESCRIBE METHOD OF CONSERVATIVE DETERMINATION OF RT_{NDT}
  - REQUIRE DETERMINATION OF PROJECTED RT_{NDT}
  - REQUIRE FEASIBLE AND NECESSARY FLUX REDUCTION PROGRAMS
  - REQUIRE PLANT-SPECIFIC EVALUATIONS THREE YEARS BEFORE SCREENING CRITERION REACHED
- o ORDER H. B. ROBINSON TO SUBMIT COMPREHENSIVE PLAN
- o FOR PLANTS THAT NEED NEAR-TERM FLUX REDUCTION OF FACTORS OF 2 TO 5 TO REACH END OF LIFE BELOW CRITERION--DETERMINE LICENSEES' PLANS AND ISSUE 50.54 (f) LETTERS AS APPROPRIATE
- o PREPARE GUIDANCE FOR PLANT-SPECIFIC PTS SAFETY ANALYSES
- o CONSIDER NEED FOR AMENDMENTS TO REGULATIONS
- o CONTINUE PROGRAM TO IMPROVE PROCEDURES AND OPERATOR TRAINING
- o CONTINUE ANALYTICAL AND EXPERIMENTAL PROGRAMS TO RESOLVE USI A-49

BACKUP INFORMATION

31. OPERATIONS CONSIDERATIONS
32. AUDIT OF PROCEDURES AND TRAINING
33. $\varnothing_T$ VS. TIME QUALITATIVE PLOT
34. EFFECTIVENESS OF FLUX REDUCTION
35. FRF TABLE FOR PWRS
36. FRF TABLE FOR PWRS
37. FRF TABLE FOR PWRS
38. ASSUMPTIONS USED BY STAFF FOR FUEL ASSEMBLY SUBSTITUTION
39. ISI
40. PLANT-SPECIFIC PTS EVALUATION
41. H. B. ROBINSON
42. H. B. ROBINSON 2 FLUX REDUCTION SCHEMES
43. H. B. ROBINSON 2 OPTIONS
44. OPTIONS FOR TURKEY POINT 3 AND 4, AND FORT CALHOUN

OPERATIONS CONSIDERATIONS

o OPERATOR ACTIONS AFFECT EVENT SEQUENCE

- INITIATING EVENT
- TAKE NEEDED ACTION
- OMIT OR DELAY NEEDED ACTION
- CREATIVE ACTION TO MITIGATE SEQUENCE
- BIZARRE ACTION TO AGGRAVATE SEQUENCE

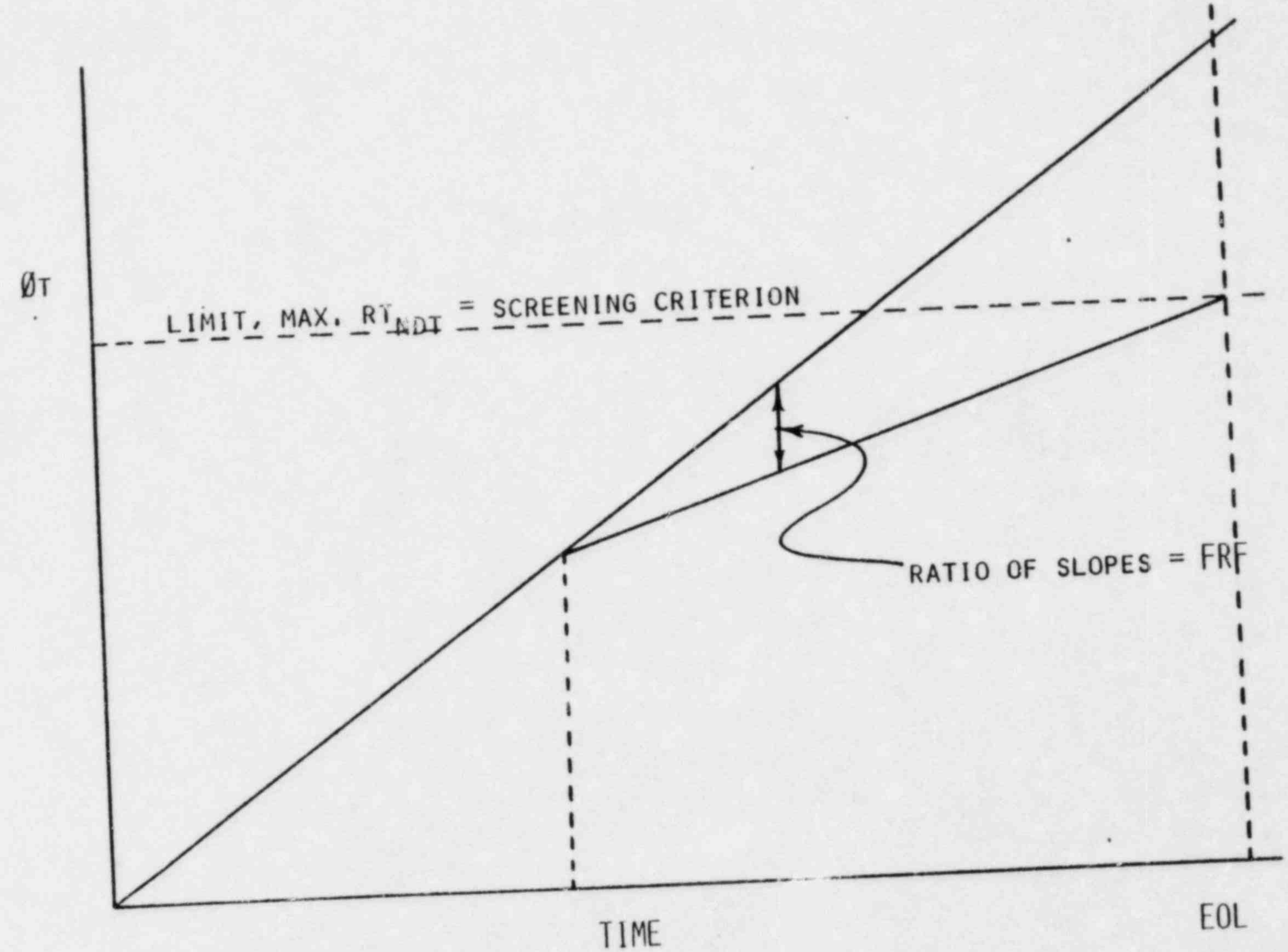
o OPERATORS NEEDS

- KNOWLEDGE AND UNDERSTANDING OF PLANT
- PROCEDURES
- INFORMATION FROM INSTRUMENTS

AUDIT OF PROCEDURES AND TRAINING

- o SYMPTOM ORIENTED PROCEDURES PROGRAM
  - HANDLE CONFLICTING REQUIREMENTS (SUCH AS UNDER vs. OVERCOOLING)
  - RESOLVE BEFORE OPERATOR IS IN MIDST OF COMPLICATED EVENT
  - INTEGRATED TMI - I.C.1 PROGRAM
- o WOG PTS REVIEW OF NEW GUIDELINES

  11 PROPOSED MODIFICATIONS
- o AUDIT AT 7 PLANTS RESULTED IN FOLLOWING RECOMMENDATIONS:
  - ACTIONS TO MITIGATE PTS SHOULD BE INCLUDED IN TECHNICAL GUIDELINES DEVELOPED FOR NUREG-0737, I.C.1, AND SHOULD BE INTEGRATED WITH UNDERCOOLING CONCERNS.
  - SUCH PROCEDURES SHOULD BE IMPLEMENTED BEFORE A PLANT IS WITHIN 3 YEARS OF THE SCREENING CRITERION.
  - THE PROCEDURES SHOULD
    - o INCLUDE ALLOWANCE FOR SYSTEM DELAY TIMES
    - o EVALUATE NEED FOR COOLDOWN RATE LIMITS FOR PERIODS < 1 HOUR
    - o PROVIDE METHODS FOR CONTROLLING COOLDOWN RATE
    - o PROVIDE GUIDANCE FOR COOLDOWN IF BRITTLE FRACTURE LIMITS ARE EXCEEDED
    - o SPECIFY A SUBCOOLING BAND
    - o PROVIDE INSTRUCTIONS FOR CONTROLLING PRESSURE FOR DEPRESSURIZATION TRANSIENTS.


ØT
LIMIT, MAX. RTNDT = SCREENING CRITERION
RATIO OF SLOPES = FRF
TIME
EOL

EFFECTIVENESS OF FLUX REDUCTION

- ABOUT 23 PLANTS DO NOT NEED
- ABOUT 10 PLANTS CAN REACH END OF LIFEWITH FRF OF ABOUT 2
- ABOUT 6 PLANTS NEED SUBSTANTIAL AND PROMPT REDUCTION
- ONE PLANT CANNOT REACH END OF LIFE BY FEASIBLE FLUX REDUCTION

As of 12/31/81

Plant, Vendor/ PV Fabricator/ MWe	Controlling element Axial or Circumferential weld or plate	RT_{NDT} Below Screening Criteria (°F)	Total Fluence E>1.MeV to Meet Screening Criteria $n/cm^2 x10^{19}$	EFPY	Fluence $(n/cm^2 x10^{19})$	Fluence per EFPY $(n/cm^2 x10^{19})$	Additional Fluence To Reach Screening Criteria $n/cm^2 x10^{19}$	Remaining EFPY in Plant Life (32 EFPY)	To Reach Screening Criteria at 32 EFPY: Fluence per EFPY $(n/cm^2 x10^{19})$	To Reach Screening Criteria at 32 EFPY: Flux Reduction Factor	FRF<1	1<FRF<2	2<FRF<3	FRF>4
Robinson-2 W/CE/665	circ.	19	1.95	7.1	1.41	.199	.54	24.9	.0217	9.2[1]				X
		12	1.95	7.1	1.64	.230	.31	24.9	.0124	18.5[1]				
Fort Calhoun CE/CE/486	axial	44	1.18	5.07	.51	.100	.67	26.93	.0249	4.0				X
Turkey Pt.-4 W/B & W/666	circ.	41	1.85	5.67	.91	.160	.94	26.33	.0357	4.5[2]				X
Turkey Pt.-3 W/B & W/666	circ.	41	1.85	5.67	.91	.160	..94	26.33	.0357	4.5[2]				X
Maine Yankee CE/CE/825	axial	54	1.18	5.90	.41	.069	.77	26.10	.0295	2.3			X	
Calvert Cliffs-1 CE/CE/850	axial	55	8.22	4.65	.68	.146	7.54	27.35	.276	.53[3]	X			
Indian Pt.-3 W/CE/965	plate	58	1.04	2.98	.167	.056	.873	29.02	.0301	1.9		X		
Yankee Rowe W/B & W/175	plate	59	4.48	14.56	1.14	.078	3.34	17.44	.1915	.4	X			
Rancho Seco B & W/B & W/913	axial	63	.77	3.54	.205	.058	.565	28.46	.0199	2.9			X	
Three Mile Island-1 B & W/B & W/792	axial	66	.75	3.52	.187	.053	.563	28.48	.0198	2.7			X	
Oconne-2 B & W/B & W/860	circ.	69	.99	4.71	.287	.061	.703	27.29	.0258	2.4			X	
Zion-1 W/B & W/1040	circ.	75	1.25	4.97	.313	.063	.937	27.03	.0347	1.8		X		
Point Beach-1 W/B & W/497	axial	72	3.48	8.07	.734	.091	2.750	23.93	.1149	.8	X			
Oconee-1 B & W/B & W/860	axial	79	1.33	5.04	.232	.046	1.100	26.96	.0408	1.1		X		
Indian Pt.2 W/CE/873	axial	81	1.18	4.40	.22	.050	.960	27.60	.0348	1.4		X		

As of 12/31/81

Plant, Vendor/ PV Fabricator/ MWe	Controlling element Axial or Circumferential weld or plate	RT_{NDT} Below Screening Criteria (°F)	Total Fluence E>1.MeV to Meet Screening Criteria $n/cm^2 x10^{19}$	EFPY	Fluence $(n/cm^2 x10^{19})$	Fluence per EFPY $(n/cm^2 x10^{19})$	Additional Fluence To Reach Screening Criteria $n/cm^2 x10^{19}$	Remaining EFPY in Plant Life (32 EFPY)	To Reach Screening Criteria at 32 EFPY: Fluence per EFPY $(n/cm^2 x10^{19})$	To Reach Screening Criteria at 32 EFPY: Flux Reduction Factor	FRF<1	1<FRF<2	2<FRF<3	FRF>4
Ginna W/B & W/490	circ.	87	4.95	8.18	.949	.116	4.000	23.82	.1679	.7	X			
Point Beach-2 W/B & W, CE/497	circ.	85	4.65	7.54	.953	.126	3.700	24.46	.1513	.8	X			
Arkansas, ANO-1 B & W/B & W/836	axial	82	1.23	4.42	.199	.045	1.031	27.58	.0374	1.2		X		
San Onofre-1 W/CE/436	axial	89	12.23	9.04	2.71	.300	9.520	22.96	.4146	.7	X			
Zion-2 W/B & W/1040	axial	93	.77	4.49	.09	.02	.680	27.51	.0247	.8	X			
Palisades CE/CE/740	axial	93	2.33	4.12	.478	.116	1.852	27.88	.0664	1.7		X		
Crystal River-3 B & W/B & W/825	axial	93	1.18	2.48	.136	.055	1.044	29.52	.0354	1.6		X		
Surry-1 W/B & W/775	circ.	100	5.50	4.88	.761	.159	4.74	27.12	.1748	.9	X			
Cook-1 W/CE/1054	circ.	100	1.94	4.56	.287	.063	1.653	27.44	.060	1.05		X		
North Anna-1 W/RG/865	plate	138	11.57	2.41	.442	.183	11.13	29.59	.376	.486	X			
Beaver Valley W/CE/833	circ.	118	2.06	1.87	.316	.169	1.744	30.13	.058	2.91			X	
North Anna-2 W/RD/890	plate	148	10.1	.77	.138	.179	9.962	31.23	.319	.56	X			
Salem-1 W/CE/1090	axial	150	3.68	2.26	.148	.065	3.532	29.74	.119	.55	X			
Oconee-3 B&W/B&W/860	circ.	129	5.04	4.78	.292	.061	4.748	27.22	.174	.35	X			
Surry-2 W/B&W/775	circ.	133	14.8	4.83	.754	.156	14.05	27.17	.517	.30	X			

As of 12/31/81

Plant, Vendor/ PV Fabricator/ MWe	Controlling element Axial or Circumferential weld or plate	RT_{NDT} Below Screening Criteria (°F)	Total Fluence E 1 MeV to Meet Screening Criteria $n/cm^2 x10^{19}$	EFPY	Fluence $(n/cm^2 x10^{19})$	Fluence per EFPY $(n/cm^2 x10^{19})$	Additional Fluence To Reach Screening Criteria $n/cm^2 x10^{19}$	Remaining EFPY in Plant Life (32 EFPY)	To Reach Screening Criteria at 32 EFPY: Fluence per EFPY $(n/cm^2 x10^{19})$	To Reach Screening Criteria at 32 EFPY: Flux Reduction Factor	FRF<1	1<FRF<2	2<FRF<3	FRF>4
St. Lucie-1 CE/CE/777	axial	135	3.02	3.52	.222	.063	2.798	28.48	.098	.64	X			
Calvert Cliffs-2 CE/CE/850	axial	140	8.48	3.63	.534	.147	7.946	28.37	.280	.53	X			
Trojan W/CBI/1130	plate	167	16.2	3.00	.207	.069	16.00	29.00	.552	.13	X			
Davis Besse-1 B&W/B&W/906	circ.	156	5.25	1.68	.111	.066	5.14	30.32	.170	.39	X			
Haddam Neck W/CE/582	axial	161	36.48	10.92	1.190	.109	35.29	21.08	1.674	.07	X			
Kewaunee W/CE/535	circ.	168	17.14	5.87	.786	.134	16.35	26.13	.626	.21	X			
Farley-1 W/CE/829	circ.	180	11.61	2.19	.370	.169	11.24	29.81	.377	.45	X			
Millstone-2 CE/CE/870	circ.	183	7.62	3.91	.219	.056	7.40	28.09	.263	.21	X			
Prairie Island-1 W/SFAC/520	axial	216	90.7	5.62	.753	.134	89.95	26.38	3.41	.04	X			
Prairie Island-2 W/SFAC/520	axial	237	292.1	5.90	.790	.139	291.3	26.10	11.16	.01	X			
										Summary	23	8	5	4

(1) The lower line in H. B. Robinson lists the staff's calculations. The differences have not been resolved as of 11/10/82. Note that the current cycle of the Robinson plant (after 12/31/81) is a low leakage cycle, therefore, the FRF would currently be lower by a factor of 2, i.e., 4.6 and 9.2 for licensee and NRC calculations.

(2) The staff has been notified by Florida Power and Light (Ref. 5) that the fluence at 5.67 EFPY was .91 x 10^{19} n/cm^2 and the projected fluence for the next 3 EFPY will be 1.39 x 10^{19} n/cm^2 i.e., the fluence accumulation rate will remain the same. These values have not been reviewed by the staff.

(3) The value of the fluence required to reach the screening criteria is based on .21% copper content in the weld seam (Ref. 6).

ASSUMPTIONS USED BY STAFF FOR FUEL ASSEMBLY SUBSTITUTION

1. CRITERION FOR FLUX REDUCTION - PEAK FLUENCE TO CRITICAL WELD
2. CORE REDESIGN ALTERNATIVES
   - RELAXATION OF APPENDIX K
   - LOWERING OF MDNBR
   - POWER DERATING
3. LINEAR HEAT GENERATION RATE INCREASED BY 20% IF APPENDIX K RELAXED
4. LOWERING DNBR BY 10% ALLOWS RAISING AVERAGE HEAT GENERATION RATE BY 20%
5. POWER REPLACEMENT COSTS = \$0.3M/DAY
6. CORE REDESIGN COST = \$20M

ISI

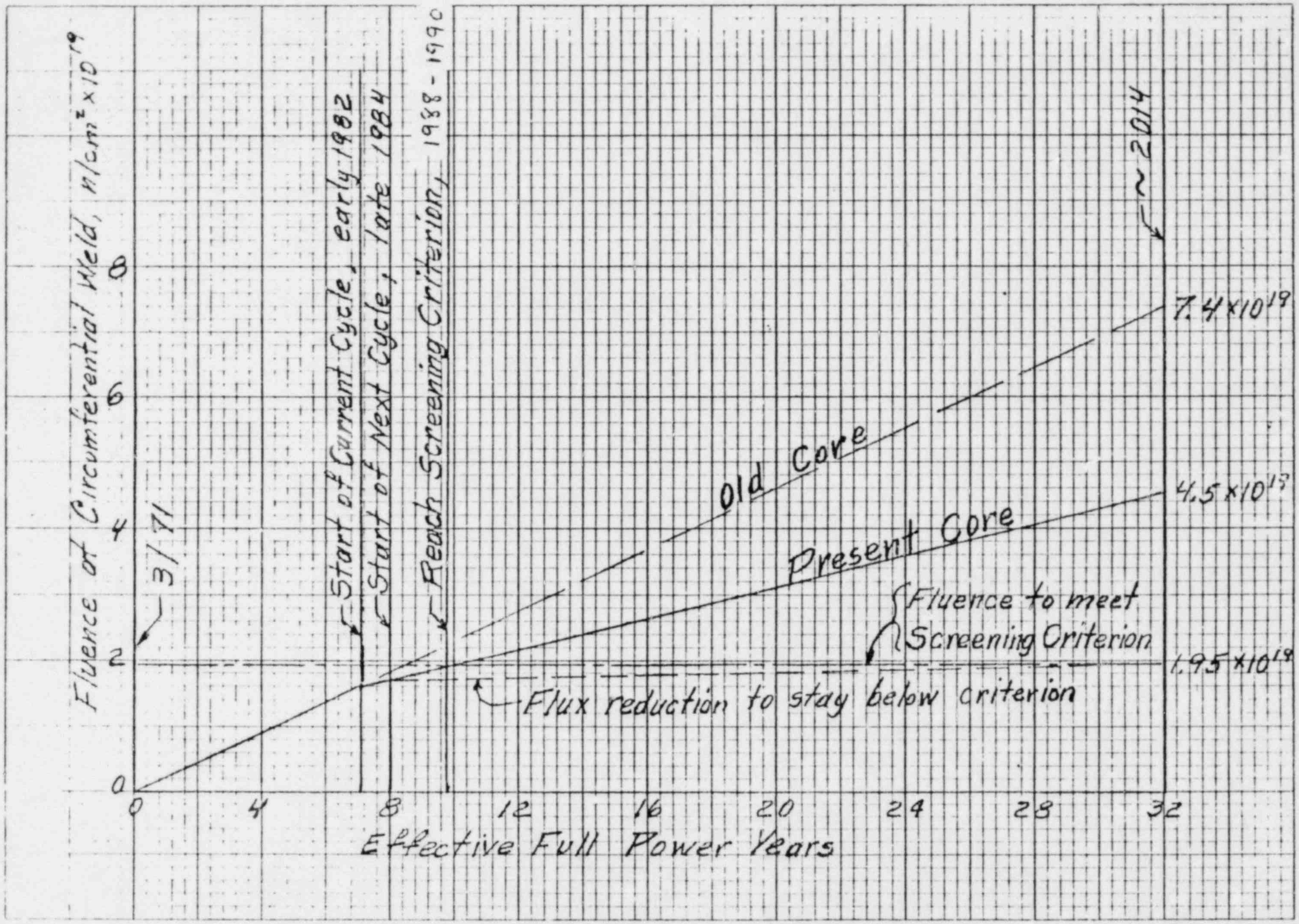
- o WELDS VOLUMETRICALLY EXAMINED AT HBR, OCONEE 1 AND 2, AND TURKEY POINT 3 AND 4
- o INSPECTION TECHNIQUES MET REG. GUIDE 1.50 AND SECTION XI REQUIREMENTS
- o INDICATIONS THAT WERE FOUND WERE MANUFACTURING INDUCED AND WERE ACCEPTABLE WITHIN REG. REQUIREMENTS
- o NO SERVICE INDUCED INDICATIONS

PLANT-SPECIFIC PTS EVALUATION

- o EVALUATION OF OVERCOOLING EVENT SEQUENCES
- o VESSEL MATERIALS PROPERTIES
- o DETERMINISTIC FRACTURE MECHANICS EVALUATIONS
- o FLUX REDUCTION PROGRAM
- o INSERVICE INSPECTION AND NONDESTRUCTIVE EVALUATION PROGRAM
- o PLANT MODIFICATIONS
  - INSTRUMENTATION AND CONTROLS
  - AUTOMATIC DEPRESSURIZATION LOGIC
  - INCREASED EMERGENCY CORE COOLING WATER AND EMERGENCY FEEDWATER TEMPERATURES
- o OPERATING PROCEDURES AND TRAINING PROGRAM IMPROVEMENTS
- o IN-SITU ANNEALING
- o BASIS FOR CONTINUED OPERATION

H. B. ROBINSON

- REDUCED FLUX BY FACTOR OF 2 IN EARLY 1982
- PROCEDURES MODIFIED AND TRAINING CONDUCTED IN RESPONSE TO STAFF AUDIT
- STAFF ESTIMATES CIRCUMFERENTIAL WELD WILL REACH SCREENING CRITERION IN 1988
- LICENSEE CONSIDERING HEATING ECCS WATER
- EXTENDED OUTAGE FOR STEAM GENERATOR REPLACEMENT PLANNED FOR 1984



H. B. ROBINSON 2 FLUX REDUCTION SCHEMES

H. B. ROBINSON 2 OPTIONS

FLUX REDUCTION FACTOR 9.2

REPLACE OUTER ROW FUEL WITH DUMMIES

INCREASE PEAK POWER 30%

15% - FUEL MANAGEMENT

15% - ALTERNATIVES

A) APPENDIX K B) MDNBR	$20M ENGINEERING DOWNTIME (REFUEL)
C) DERATE	$20M + $10M/YR

OPTIONS FOR TURKEY POINT 3 AND 4, AND FORT CALHOUN

FLUX REDUCTION FACTOR (FRF) 4 - 4.5

"LOW LEAKAGE" ~ 2

4 - 12 ELEMENTS REMOVED ~ 2

ENGINEERING	$20M
FUEL	NEGLIGIBLE

NO DERATING

12/81

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C&R (Natalie)

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Meeting Title: Briefing on Pressurized Thermal Shock

MEETING DATE: 12/1/82 Open X Closed ___

ITEM DESCRIPTION:	Copies Advanced To PDR:	DCS COPIES: (1 of each Checked) Original Document	May be Dup*	Duplicate Copy*
1. Transcript (with viewgraphs attached)	1	1		
2. Secy-82-465 (with errata pages for Enc A and Encs. A-G)	2		1	
3.				
4.				
5.				

*Verify if in DCS, and change to "PDR available."

(PDR is advanced one of each document, two of each SECY paper.)