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UNITED STATES NUCLEAR REGULATORY COMMISSION'S
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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METALLURGY AND REACTOR FUELS SUBCOMMITTEE

OPEN SESSION

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TUESDAY, MAY 3, 2016

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B1, 11545 Rockville Pike, at 1:05 p.m., Ronald G. Ballinger, Chairman, presiding.

COMMITTEE MEMBERS:

RONALD G. BALLINGER, Chairman

CHARLES H. BROWN, JR. Member

DANA A. POWERS, Member

JOY L. REMPE, Member

PETER RICCARDELLA, Member-at-Large

GORDON R. SKILLMAN, Member

JOHN W. STETKAR, Member

DESIGNATED FEDERAL OFFICIAL:

DEREK WIDMAYER

ALSO PRESENT:

KATHRYN BROCK, RES

MARK KIRK, RES

MARVIN LEWIS, Public Participant*

ANDREA D. VALENTIN, Executive Director, ACRS

*Present via telephone

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P R O C E E D I N G S

(1:05 p.m.)

CHAIRMAN BALLINGER: Okay. Good afternoon. The meeting will now come to order. This is a meeting of the Advisory Committee on Reactor Safeguards Subcommittee on metallurgy and reactor fuels. I'm Ron Ballinger, Chairman of the Subcommittee.

MEMBER POWERS: What is wrong with you?

CHAIRMAN BALLINGER: ACRS members -- and I use that term lightly -- in attendance: Pete Riccardella, Gordon Skillman, Dana Powers, John Stetkar, Charlie Brown, and the esteemed Joy Rempe. Derek Widmayer of the ACRS staff is the Designated Federal Official for this meeting.

The purpose of today's meeting is for the NRC staff to discuss the final draft Regulatory Guide 1.230. Regulatory guidance on the alternate Pressurized Thermal Shock rule and draft final report NUREG-2163, technical basis for regulatory guidance on the alternate Pressurized Thermal Shock rule, otherwise known as 10 CFR 50.61a.

The Subcommittee considered this matter at a Subcommittee meeting held in October 2015 and many others but decided to meet again and hear from the staff after it received comments on the draft documents. The Subcommittee will gather information, analyze relevant issues and facts, formulate proposed positions and actions as appropriate, for consideration by the full Committee at the upcoming June 235th meeting of the ACRS.

Rules for participation in today's meeting were announced as part of the notice of the meeting published in the Federal Register. Detailed proceedings for conduct of the ACRS was previously published in the Federal Register on October 1, 2014. The meeting will be open to the public, except for a portion of the meeting at the end which will be closed in order to discuss public comments and the proposed NRC staff resolutions to those comments.

We have received no written comments or requests for time to make oral statement. A transcript of today's meeting is being kept and will be made available, as stated in the Federal Register Notice. Therefore, we request that meeting participants use the microphones located in the meeting room when addressing the Subcommittee and push the little green button when you need to talk. Participants should first identify themselves and speak with sufficient clarity and volume so that they may be readily heard.

A telephone bridgeline has been established for this meeting. To preclude interruption of this meeting, please mute your individual telephones and lines during presentations and the Subcommittee discussion. We ask that attendees in the room please silence all cell phones and things that beep and other devices that make noise to minimize disruptions.

And we'll now proceed with the meeting. I'll call on Mark Kirk. Whoa.

MS. BROCK: Good afternoon.

CHAIRMAN BALLINGER: Call on Kathryn Brock -- boy, that is a good entrance -- Deputy Director of the Office of Research, Division of Engineering, to make introductory remarks. Thank you.

MS. BROCK: Thank you very much. So it's my pleasure to introduce Dr. Mark Kirk, who is going to be presenting the NRC's response to public comments on what's now designated as Reg Guide 1.230 and its supporting technical basis, NUREG-

2163.

These documents provide methods acceptable to the staff by which licensees could choose to implement the alternate Pressurized Thermal Shock rule, or PTS. As Mark will talk to you about in some detail, this issue on PTS goes back around two decades, and Mark has been always happy to come to ACRS to address this committee and your comments have always been very helpful to us, and we appreciate it.

So at this stage, we're ready to move forward with the final reg guide, subject to this committee's approval. Thanks very much.

CHAIRMAN BALLINGER: Okay. All yours.

MS. BROCK: Okay, all right. Thank you. Well, hopefully, my closeout performance here. So in terms of an overview, I'll just give some background on the alternate PTS rule development, on the PTS rule regulatory guide, including the reg guide development process and its current status, and provide an overview of the contents of the tech basis and the reg guide. The tech basis is a companion NUREG that went out for public comment at the same time as the reg guide.

I'll provide a few slides on plants

that might possibly use 10 CFR 50.61a -- and I'll probably go back and forth between saying 50.61a and the alternate PTS rule, they both mean the same thing -- and Reg Guide 1.230 in the future. Then I believe, at that point, the meeting gets closed to discuss the staff's responses to public comments on the reg guide and tech basis.

And at the end, we're looking for this committee to either send a memo to NRC Research approving the reg guide and NUREG for publication or to send a letter to the EDO, of course, objecting to that. But you'll figure that out, I'm sure.

MEMBER POWERS: ACRS speaks only through its letters.

MR. KIRK: Yes.

CHAIRMAN BALLINGER: And that's up to the full Committee.

MR. KIRK: Okay, okay.

MEMBER REMPE: And if we were to issue a memo, like a Hackett-Gram or a Valentine memo, it would not be an approving thing. It would just say we have no comments on this thing.

MR. KIRK: Okay, okay, thank you. So the first topic is just to set the scene, the quick overview -- I say quick in a bit of quotation marks -- on the development and background of the alternate rule. This is the last 18 years of my life. I was thinking of including a picture of myself in 1998, but the contrast to my current state of decrepitude was too horrible for me to reconcile, so I went without pictures. You're welcome.

CHAIRMAN BALLINGER: They had film back in those days. Is there any film left?

MR. KIRK: I think it was a Daguerreotype, but I'm not really sure. Anyway, this project started shortly before I joined the NRC staff in 1998, and I quickly got involved in it and it's been very interesting. And the first two years or so, we spent a lot of time meeting among ourselves, having public meetings, interacting with our industry counterparts to develop a PFM Code to simulate what would happen to a nuclear reactor pressurized water reactor in the unlikely event of a Pressurized Thermal Shock Event.

Once we had a code, of course it didn't work perfectly the first time, so there were several modifications to the code. And we were briefing the ACRS all along the way. We used to come here about twice a year, as I recall.

And, finally, at the end of the phase that I've called building the technical case in the 2005 - 2006 time frame, the technical reports were all given a favorable nod by this committee. And about a year later, the Commission directed the staff to begin rulemaking.

The rulemaking process itself, in this case, took about two and a half years, as my colleague sitting in the back, Matt Mitchell, remembers. I believe he had hair at that time.

We went out for two rounds of public comments and, ultimately, arrived at what was published on, I believe, January the 3rd, 2010 as the alternate PTS rule. As government printing goes, it then took about six more months and three re-publications to get everything correct.

Since that time, we've been working on guidance for using the rule. The industry, however, works a little bit quicker than the government and, actually, two submittals came in to use the rule before we get the draft guidance released for public comment.

Beaver Valley submitted in the middle of, in the summer of 2013. Palisades submitted in the summer of 2014. I'll tell you the rest of the story later, but "Beaver Valley submits" is crossed out because they later elected to withdraw their submittal for reasons I'll explain later. But the Palisades submittal was fully reviewed by the staff, went through several rounds of RAIs, two as I recall, and was eventually approved a little before Christmastime of last year.

Pertinent to the discussions here, Draft Guide 1299, which is subject to the favorable ratings from this committee and the printing press is still working will become Reg Guide 1.230, was released for public comment at the end of 2014 or early 2015, and today we're talking about those public comments and I'll say the relatively small ways in which they've changed the draft reg guide and how we plan on moving forward.

A little bit of background. What's in 10 CFR 50.61a and why was it developed? And as it's indicated on the slide, this was explained in Chapter 1 of NUREG-2163, which you'll also hear me call the tech basis document.

So the path to 50.61a, we'll talk a little bit about the motivation for doing this at all, the overall approach that the staff employed, the key results, and a brief discussion of the provisions of the alternate rule.

So, of course, the original PTS rule, to which this is an alternate, was developed in the early 1980s and promulgated, I always get this wrong and I shouldn't, I think in 1986. At the time, there was, I think, broad recognition throughout the nuclear community and among the NRC staff that the calculations and the data that supported the original PTS rule, 50.61, had within it a lot of embedded conservatisms that, at the time, were not seen as being necessary to be made better because the nuclear industry was a lot younger then, plants weren't coming up on 40-year licenses or going for 60 or 80, so the conservatisms that were embedded in the embrittlement screening criteria that are still part of the original PTS rule 50.61 weren't seen to be in any way limiting or excessively conservative.

I should say, from that time, there was talk among various parties of an interest in revising the rule or doing a better job. That finally culminated with staff interest pushed forward by Mike Mayfield in the late 1990s and was motivated by several things. One was, just looking at it from a technical viewpoint, was a desire to do a better job, to treat everything more realistically. But, of course, just technically doing a better job isn't enough reason to do something. There are also some key regulatory motivations, and they're listed here. One is that doing a better job would reduce unnecessary burden associated with the original rule. As I said, the technical insights indicated that the then existing screening criteria were more conservative than were needed to maintain safety and that those screening criteria don't necessarily increase the overall plant safety and, in fact, could divert resources on other more risk-significant matters.

Part of the reason motivating the alternate rule was the experience, and I'll say, I think, routinely bad experience, from the early 1990s with plant-specific analysis using PRA and PFM as a means of showing that operating beyond the then existent 50.61 screening criteria was acceptable, otherwise known as Yankee Row. So there was an interest in doing something more generically for the fleet with the hope that things like Yankee Row and the associated uncertainties associated with that process would not be repeated.

And also, as we got into the late 1990s - early 2000s, things that weren't apparent in the mid-1980s, like license renewal, and now I've been around long enough I can say license renewal-renewal or the NRC's acronym for that is SOR, those things weren't even thought of. Now they're thought of. Now license renewal has happened, and we're talking about subsequent license renewal. So having screening limits that are overly conservative creates an artificial impediment to those processes.

MEMBER SKILLMAN: Mark, before you change that slide, for those who have been around for a long time, 300 degrees Fahrenheit and 270 Fahrenheit are numbers that we've all come to know and trust. For instance, that's about where you go ahead and give permit to the fourth pump start, so you don't lift your fuel. That's where the density has become low enough that starting a fourth reactor coolant pump doesn't cause your fuel to chatter. It's married to the springs. 270 is commonly a run back. The secondary dumps or the atmospheric dumps might bring the plant back to 270 automatically.

Those numbers were chosen many years

ago based on knowing how a P will operate. And I think if one were to check the Westinghouse, the Babcock, and the CEs, all used approximately those same numbers. And so I'm wondering if simply by anointing them as too conservative, the baby being thrown out with the bath water, something is being lost.

MR. KIRK: I'd like to just clarify what I think you told me. You're saying that, in plant operation, those numbers mean something?

MEMBER SKILLMAN: Certain events have been associated with these numbers.

MR. KIRK: Yes.

MEMBER SKILLMAN: And I'm not suggesting that they, in themselves, represent a conservatism that should be retained. All I'm saying is, when you look at those numbers and if you're an old P handler, you say I know what those numbers mean.

MR. KIRK: Yes, in tech specs, they're all over the place. And I'm, well, I'm not a plant operations person, but I certainly wouldn't be suggesting that that operational practice should change. And, in fact, I can say for certain that, to the analyses that we did reflected current plant operating procedures. So to the extent that we analyzed transients involving the things that you've said, and I'll just have to plead ignorance because, again, that's not my specialty, the assumption moving forward is that those operational events would not be changing as a result in the change in the embrittlement screening criteria.

I'll just say I haven't personally, before you mentioned this which probably reflects that I should get out more often, heard anybody say, oh, now, we change these plant operational procedures because the NRC has put out a new --

MEMBER SKILLMAN: No, you can't because you still have those other thermal hydraulic issues that you have to deal with --

MR. KIRK: Right, right.

MEMBER SKILLMAN: -- that is like when the density is appropriate, so you don't lift your fuel if you start the fourth --

MR. KIRK: So I think there are other, I mean, I think you've maybe provided a better answer than I have. There are other reasons to keep those operating procedures in place that are completely different than screening limits related to plant integrity.

MEMBER SKILLMAN: Thank you.

MR. KIRK: Okay. So our overall approach was that we started with commissioned guidance in the form of the Safety Goal Policy Statement, the June 1990 Safety Requirements Memorandum and Reg Guide 1.174 to derive a performance metric in terms of -- well, basically, here the conservative assumption was that large early release frequency was equal to yearly frequency of through-wall cracking, and so that was set at a one times seven to the minus six level, and then we performed a number of probabilistic fracture mechanics analyses driven by PRA at the start to define the sequence of things that could go wrong that could lead to a Pressurized Thermal Shock or excessive cool-down and the frequency with which they happen. The PRA then fed the thermal hydraulic analyses to define the pressure temperature and heat transfer boundary conditions that go into the structural mechanics and fracture mechanics analysis. There are a bunch of other inputs that aren't shown here.

But that then gives us a conditional probability of through-wall cracking. It's then multiplied, matrix multiplied by the event frequencies, to estimate the yearly frequency of through-wall cracking. We did that analysis for three plants, or I should say models of three plants, that we studied in detail, those being the Palisades plant, the Beaver Valley plant, and Oconee; developed from that this relationship between vessel damage as quantified by vessel transition temperature, showed that, of course, as that increases, as embrittlement increases, the yearly frequency of through-wall cracking increased. Used that to develop a screening criteria consistent with defense-in-depth principles and then looked at what were the key things driving these values to see if we could generalize those results to all plants in the fleet. And I'll talk a little bit more about that as we go on, which is now.

So in terms of some of the key results I'd like to highlight: What are the operational transients that most influence the PTS risk? Similarly, what are the material features that most influence the PTS risk? And then sort of the key question to our development of a rule that could apply to all PWRS is to see if these dominant material features and transients are, more or less, similar across the fleet or do they vary by a plant-by-plant or designer-by-designer basis? And then talk about finally the new embrittlement -- well, then new, this is a slide from I think 2007 -- embrittlement screening criteria based on these calculations.

So we did a pretty thorough job at modeling, I'll just say all the classes of cool-down transients that could occur under postulated accident conditions. So we had a spectrum of pipe breaks from very small to very large, stuck-open valves that later re-closed. On the secondary side, we had main steam line breaks and basically tried to model the plant as accurately as we could for things that could go wrong and ruin your day, from a plant operations perspective.

Looking at all of that, so we modeled all these different variations of cool-down events with and without pressure. But then when we got to looking at the results, things pretty much fall into one of three categories, which I've depicted here. I should say things fell into one of three categories for cool-down events that had risk significance.

In the end in this project, we

calculated an awful lot of zeros, so one category with significant cool-downs is medium- and large-diameter pipe breaks. The second category is stuck-open primary side valves. So a stuck-open valve is something like a small-diameter pipe break, but the key thing there is the valve re-closes later in the transient and leads to a pressurization spike.

And then the third is main steam line breaks, and all of these are plotted versus embrittlement and degrees Rankine, and everybody always asks me why I use degrees Rankine, and I think I had a good technical reason years ago and, in the fullness of time, it's been revealed that it just annoys people. So as Candidate Clinton said, it seemed like a good idea at the time, but now I realize it was a mistake.

So this slide 16 is pretty much the same as slide 15 but easier to look at because I've re-expressed the through-wall cracking frequencies as ratios of each other. And this really more better communicates the message, which is -- and now I've gone back to degrees Fahrenheit just to confuse everyone -- at lower levels of embrittlement, the stuck-open valves that re-close late in the transient and lead to a re-pressurization spike, they're the transients that are dominating a risk because you need that light pressure spike to get a crack going in, admittedly an embrittled but a not too embrittled material.

However, as you embrittle the material more and more, of course all of these through-wall cracking frequencies are going up, but the rate of increase per increment of embrittlement, if you will, for the medium- and large-diameter pipe breaks is larger, such that when you get out to reference temperatures in the range where we're setting our screening criteria, it's actually the medium- and large-diameter pipe breaks that are dominating the risk, that are making up 70 to 80-percent of the risk.

Sort of interesting change from the results from the early 1980s is the main steam line breaks, which in the first analysis of PTS in the 80s were seen to be the risk dominant transient, now become almost a bit player, and so you ask why. And this is where modeling assumptions become important, and actually there are two illustrations here where modeling assumptions become important. In the original PTS analysis, there was no risk significance to medium- and large-diameter pipe breaks because they were eliminated from the analysis a priori. It was assumed that you needed pressure, you needed the "P" in PTS to get a through-wall crack.

Since the events weren't analyzed, of course they couldn't be risk significant because they were assumed to be zero. When we actually analyzed them, we found that when you get out to sufficient levels of embrittlement, there's not enough crack risk capacity in the material, and they did indeed go through-wall.

So a big, you know, sort of change in perspective for what transients matter in PTS and what don't came in this analysis when we learned that, well, when we analyzed something that we had previously eliminated based on, shall I say, engineering judgment, we find out that it really was risk significant, so it should have been analyzed before.

Conversely, the opposite is true of main steam line break. In the circa 1980s analysis, the main steam line break was analyzed as a whopping fast cool-down, which, of course, it has to be because you're breaking a huge diameter pipe, so you're creating a big heat transfer area. But to be conservative, the steam line break was assumed to go down to essentially ambient temperature water, something in the 50 - 60-degree Fahrenheit range. Of course, that can't happen in the primary because the main steam lines are secondary, so the cold is the primary when the main steam line breaks is the boiling point of water, 212 Fahrenheit or 100 degrees Celsius.

When we included that more realistic model in this set of analysis, we found out that, yes, the main steam line break contributes something but not nearly as much as we saw before.

So, you know, this graph I think illustrates some lessons learned in building these models, but it also, I think, provides a very useful lesson moving forward that your perception of reality of course depends on what you model and what you model depends on how you decide to model it. And that drives plant decisions, so we should take care.

MEMBER RICCARDELLA: Mark, the new limits, they have separate limits for axial weld plate, circ weld, and forging, and, yet, the last two slides you just said maxed our T. Is that any specific --

MR. KIRK: In here, I've just added it versus the axial weld reference temperature just really for purposes of --

MEMBER RICCARDELLA: All right. Because that governs --

MR. KIRK: -- for purposes of illustration, but the reason, I think I've said all this so I'll skip this slide, but since you've raised it, the reason for the maximum, the differences in the maximum reference temperature limits, depending upon, essentially, the product form is best illustrated on this slide now, slide 18 in your pack, is that -- I'm sorry. I should back up just a little bit.

In the probabilistic fracture mechanics models, we see different flaw size populations and different flaw orientations, depending upon what product form in the RPV shell it's going into. So welds get flaws drawn from particular flaw distribution, but they have the orientation of the weld itself because they're all nominally lack of fusion flaws. So axial welds get axially-oriented flaws, circumferential welds get circumferentially-oriented flaws.

So we just compare on your screen the left most and right most slides. You're seeing here flaws from the same population, but the orientation has turned 90. And that makes a major difference when you're trying to propagate a crack through the wall of a pressurized sander in that, as you grow the axial flaw, the deeper the axial flaw gets as it goes through the cylinder, the driving force to fracture just keeps going up and up and up and so, essentially, it just gets pushed out the back of the cylinder.

MEMBER RICCARDELLA: Part of it is P over T versus P over 2T, right? That's one part of it.

MR. KIRK: Well, that's one part of it.

MEMBER RICCARDELLA: The other part is the --

MR. KIRK: But, I mean, so the magnitude is certainly higher for the axial flaw, but there's also, due to just the geometry of the cylinder, as you make the circumferential flaw deeper --

MEMBER RICCARDELLA: The K equations are different.

MR. KIRK: Yes, the K equations are

different, and so the circ flaw equations hit a peak K somewhere around 30 to 40 percent of the way through the wall under the fixed script conditions that you get in a thermally-driven event. So there's a very natural crack arrest mechanism for circumferential flaws, and, as a result, if you look at any given reference temperature level, if you take your 750 Rankine -- forgive me -- and you go to the curve for the axial flaws, you've got about a 10 to the minus 6 through-wall cracking frequency, whereas that same embrittlement in a circ weld, you're down nearly two decades lower.

And the curves you see here is the reason why the reference temperature screening limit, screening criteria I should say, in the rule are so significantly different for the different product forms. The plates are, you're drawing from a different population than the welds. And, also, since there's no preferred orientation in plates for flaws, they're seated 50-percent circumferentials, 50-percent axial. So they wind up being intermediate.

MEMBER RICCARDELLA: But, in general, you have smaller flaws --

MR. KIRK: Yes. And, in general, the

flaws are much, yes, much smaller. But, you know, an interesting -- well, in the original, in 50.61, of course there's a difference in the screening criteria for axial welds and circ welds, a difference between 270 and 300. You can't see the screening criteria here, so that difference is reflective of this difference in driving force. But in the new calculations, the difference in temperature screening criteria is much, much more than 30 degrees.

MEMBER SKILLMAN: Excuse me. Can you explain what the first bullet means, please?

MR. KIRK: So the primary side fault. So of the three dominant or sort of dominant transient classes of primary side pipe breaks, there's primary side pipe breaks, there's stuck-open valves in the primary side that re-close later, and there's main steam line breaks. So only one of those is the secondary side fault, the first two being primary side faults, and they together are responsible for pretty much 95 percent of the calculated risk.

MEMBER SKILLMAN: And a 35-degree Fahrenheit is your ECCS tank in-flow temperature minimum?

MR. KIRK: Yes, if you have storage on the outside.

MEMBER SKILLMAN: Okay, thank you. Now I understand.

MR. KIRK: Yes, okay. Sorry. It was that point you were focused on, yes. And I should say in the analysis we did look at differences between ECCS injection temperature, and it, of course, does make a difference.

MEMBER RICCARDELLA: Was that a random variable?

MR. KIRK: No, we modeled both, and now you're asking me to go back over a decade in my memory. But we modeled both, and it was weighted by an event frequency. You modeled hot, cold and hot?

MR. KIRK: Cold and hot, yes.

MEMBER RICCARDELLA: Okay, got it.

MR. KIRK: But, you know, as an example, if somebody wanted to come in -- so in the screening criteria, the significance of that particular variable doesn't really come out. That's been, I'll say, sort of mushed into the screening criteria by the fact the screening criteria are based on upper bounds to these three curves here. So we're taking the worst of the conditions modeled, whereas, say if somebody wanted to come in and do a plant-specific analysis and that plan happened to be say in the southern part of the United States where it never gets that cold or they happen to have indoor refueling water storage, they could make that argument and show that the specific calculations for their plant would not be as severe as we've assumed here.

And this just shows, again, slide 19 shows, and I think a little bit of an easier format, the same message as 18, that, for all intents and purposes, it's the axial weld flaws and the properties of the belt line materials that can be associated with axial weld flaws that drive the PTS risk and that the flaws and plates and the circumferential weld flaws -- excuse me -- play a much more minor role.

So we've already talked through this. The axial cracks dominate risk due to their orientation and, well, due to their orientation, and so it's the properties of the materials associated with the actual cracks that dominate the screening criteria, which would be the axial weld properties or the properties of the adjacent plate, whichever is worse.

This is now, you know, sort of one of two ways of looking at the results, and this is, in fact, the way it was codified into the reference temperature limits in 50.61a. Since I like graphs better than tables, this is a graph that depicts I'll say a portion of the tables in 50.61a.

So if we had a plant that was made of axial welds and plates, you know, here would be the screening criteria in the table for the axial weld on the horizontal access, the screening criteria on the plate on the vertical axis, and then you'll also see in the tables that there's a combination, a limit on the combination of those two. And really all those are in the tables is an attempt to depict, I'll say, the ISO through-wall cracking frequency surface that came out of curve-fitting these three curves. So what we're saying here, and I think I must have that slide, yes, I have that slide, unfortunately, some place else, what we're saying here is that the through-wall cracking frequency is limited to 10 to the minus 6. It then arises due to the sum of the part due to the axial weld reference temperature, the plate reference temperature, and the circ weld reference temperature, and you can invert that equation and express it in terms of reference temperatures, as we've done in the rule.

The graphs also depict the fact that the rule, that these screening criteria in the rule depend on the thickness of the wall of the vessel. And that's simply a reflection that this is a thermally-driven event, so the thicker wall supports higher stresses during thermal shock so more driving force.

MEMBER RICCARDELLA: The thermal stress?

MR. KIRK: Right, right.

MEMBER RICCARDELLA: Not the flaw size?

MR. KIRK: Well, the flaw size, I mean, the flaw sixes are, there's a lot reflected in here. But the differences based on thickness are a reflection of the thermal stress effects.

So what you see here, this is a graph actually from NUREG-1807 where, based on plant-wide data we had available at the time and based on, I must say, a now defunct view of capacity factor -- here we used a capacity factor of 80 percent to represent 60 years. Of course, we know it's higher now. But this showed that all the dots represent the operating PWRs, and they're all, at least based on this generic analysis -- of course, people have to do a plant-specific analysis, but based on a simple examination of the fleet, it seemed that everybody would remain compliant with 50.61a if they chose to use it through the end of 60 years.

Just another way to look at these same data is to look at histograms of the distributions of reference temperatures in the fleet, again using the same 48 EFP-wide data, and overlay those histograms on the results, the through-wall cracking frequency results that set the screening limits. And, you know, just to show you how to read one of these, you look at the, in this analysis, the highest estimated axial weld -- I'm sorry -- the highest estimated reference temperature in an axial weld was a little bit under 740 Rankine, so that's what that bar represents. And if you go up and over, that's getting you a through-wall cracking frequency a little bit less than 10 to the minus 7. Obviously, these graphs would need to be revised today, but this is just what was published in NUREG-1807.

So in both cases, both slides 21 and 22 are showing you a consistent picture that the plants that were operating at the time are bid inside the 50.61a screening criteria in terms of reference temperature. And, of course, that also means that the estimated through-wall cracking frequency is below 10 to the minus 6.

So everything I've done so far gives you a very quick overview of the information that we've developed to support the alternate PTS rule. Now we'll do a whirlwind tour through the alternate PTS rule itself. You need to meet three gating criteria to use the rule. You need to have a plant whose construction permit was issued before 2010, and I'm going to talk about the reasons for each of these in detail. You need to show that the embrittlement trends, as revealed by the plant-specific surveillance program for your plant, follow those assumed in the calculation of these through-wall cracking frequencies, and you also need to show that the flaw population in your plant, as revealed by ISI, is represented well or bounded by that assumed in the calculation.

Having made all those checks, you then demonstrated that, yes, the screening criteria in 50.61a would be appropriate to use for your plant.

CHAIRMAN BALLINGER: There's a mention

of ASME code also, right? It says that the plant was designed in accordance with a particular revision of the ASME code --

MR. KIRK: Yes, or earlier, I think.

CHAIRMAN BALLINGER: Yes, or earlier. I forget. 1989 or something like that? I don't --

MR. KIRK: You're right. I'm not exactly sure how that --

CHAIRMAN BALLINGER: Yes, that was one of the checkmarks.

MR. KIRK: Yes, yes, yes.

MEMBER SKILLMAN: 1998 edition or earlier.

CHAIRMAN BALLINGER: 1998 edition or earlier.

MR. KIRK: Okay. And, again, that was simply a reflection of the population of plants that formed the basis for the calculations that led to these screening limits. So let's take that in the construction permit. In practical terms, there's not a lot of changes in the ASME code pre-'98 or post-'98 that's going to affect these calculations. But all we're saying in the rule is if you want to apply theses limits to a newer plant or to a later ASME code-version plant, it's the responsibility of the licensee to make the case that these same screening criteria apply, the NRC isn't taking it on itself.

MEMBER RICCARDELLA: But you'd have to assume that a newer plant would be pretty smart about their chemistry that they put in the --

MR. KIRK: You would assume that. Certainly, I would not expect somebody to be building a high-copper plant nowadays, unless they're Rip Van Winkle.

So a quick comparison of 10 CFR 50.61 to 10 CFR 50.61a. You know, it must be said that 50.61a has less restrictive reference temperature or embrittlement screening criteria, and that enables longer operations licensable to this provision of the rules. But a gating criteria must be satisfied to use that alternative rule.

So there's sort of three steps here. There's the reference temperature screening criteria, which we said is less restrictive in the voluntary rule. We have a similar somewhat more stringent plant-specific -- sorry, my language is bad -- plant-specific surveillance data check. You need to go through a larger battery of statistical tests, but, frankly, that's a few more columns in your spreadsheet. That's really not a big deal.

The more significant hurdle to using the voluntary rule versus 50.61 is 50.61 doesn't have an inspection requirement, whereas 50.61a does. And the purpose of the inspection requirement is, of course, acknowledging that the population of flaws that went into the probabilistic fracture mechanics calculation significantly drives the results of that calculation. We want to have a common-sense check to see that the flaw population assumed in the calculation well represents or bounds that found in any particular plant. And that's why the inspection requirement is in 50.61a.

MEMBER RICCARDELLA: I mean, all the plants have inspection requirements from --

MR. KIRK: Well, yes, yes, yes.

MEMBER RICCARDELLA: It's just that --

MR. KIRK: But not as --

MEMBER RICCARDELLA: -- your inspection relative to the flaw assumption.

MR. KIRK: Right, right. I was just speaking in terms of the PTS rules --

MEMBER RICCARDELLA: And help me --

MR. KIRK: -- not the ASME

requirements.

MEMBER RICCARDELLA: How is for axial welds 222 less restrictive than 270? In the new rule, for axial welds, if it's a thick wall, it's 222 degrees.

MR. KIRK: Every time I do this, somebody asks a question I haven't had before, and I think this is the one for today. Thick welds? Well, okay, first, one thing that might get me out of this -- 222? Oh, good. 222 plus 60 is still higher. Because in the alternate rule, there's no margin because the margin has already been included in the limit.

MEMBER RICCARDELLA: I remember. Thanks.

MR. KIRK: Good. Not a new question. Okay. We'll keep going. So now we'll get into the provisions of the regulatory guide, which, you know, tell you in a little bit more detail than is practical to include in the rule a method that the staff finds acceptable to comply with the rule. So the bureaucratic slide on time line, and I have to keep reminding myself of this -- oh, see, there's the arrow on the slides. Reg Guide 1.230 is equal to Draft Guide 1299.

So in September 2013, draft guide development begins, and I should credit here my former colleague, Gary Stevens, who, with me, did a lot of this, but he found greener pastures back in industry, not much thanks to Member Riccardella. So that's why I'm alone up here.

MEMBER RICCARDELLA: I had nothing to do with it.

MR. KIRK: I'm sure you didn't. Anyway, Gary Stevens worked with me a lot on this and a lot of the credit for this goes to him. We had our first briefing with you when Gary was sitting beside me in October 2014. Since that time, in March 2015, we sent out the draft guide and the NUREG for public comments. We received those public comments in May 2015. In another era, sorry. In February 2016. We didn't get concurrence before we received the comments. We got final staff concurrence, I should say from the technical offices. NRR, RES, and NRO have all concurred on the resolution of the public comments. OGC has not. We'll explain this a little more, I'll explain this in a little more detail later. We just ran up against a timing issue here. OGC had some comments about format and needing more details and responses to certain comments. I don't think they had anything fundamental that they found wrong with it, but we still haven't cycled it back through OGC to get their final approval. We will do that after this meeting.

Obviously, May 3, 2016 -- I finally got the year right -- is today's briefing. And then, in the future, we hope to incorporate any recommendations that you have into the reg guide and NUREG, send this and the public, and the resolution to the public comments, through the Office of General Counsel for a no legal objection finding, and then, finally, publish the reg guide and the NUREG on the Federal Register with the most optimistic time frame for doing that, assuming no significant bumps along the way, being about two months from now.

MEMBER STETKAR: Mark, I always feel compelled to do this, and you've done it a few times, both on the slides and orally. This is an ACRS Subcommittee, so you're not briefing the ACRS.

MR. KIRK: Yes, I'm sorry, I'm sorry.

MEMBER STETKAR: Any comments made during this meeting are strictly individual comments, so they have no bearing on an ACRS opinion. Dr. Powers mentioned that briefly earlier, but you're perpetuating this notion that you're briefing the ACRS. You're not.

MR. KIRK: It shows my total ineptitude with --

MEMBER STETKAR: Well, it's only important because this is a meeting that's on the public record, and we don't want there to be any confusion about comments that are made by individuals in the meeting versus conveyance of an ACRS opinion on the matter.

MR. KIRK: I'll try to remember to correct that before I say it the next time, but I might still get it wrong.

Okay. So the regulatory guidance. Criteria regarding data construction, I think we already touched on this. The rule and the related reference temperature screening criteria were based on analysis of three currently operating PWRs, so we got our insights from plants in current operation designed on past editions of the ASME code.

We did not assess the effect of new reactor designs and new materials of construction on those screening criteria. Therefore, if a licensee wanted to use the alternate PTS rule for one of those newer plants, it would be up to them to demonstrate the applicability of this rule to the newer plants.

MEMBER POWERS: Would that include experimental data?

MR. KIRK: It could. There's no --

MEMBER POWERS: What would be the criterion, do you suppose, if the staff would come back and say you've done an admirable job trying to extrapolate from what we have to what you have, but we'd really like to see experimental data to validate this or something like the equivalent of this 60 effective full-power years?

MR. KIRK: Well, one thing I've learned in my nearly two decades with the NRC staff is saying that Mark's opinion is a surrogate for all the staff is --

MEMBER POWERS: I didn't say --

MR. KIRK: However, if it was me and knowing what I think I know, what I would personally be interested in is, quite frankly, more on the reactor operations side than on the materials side. And maybe that reflects too much confidence in my part of the materials side. On the materials side, we're using basically the same grades of steel, same welding techniques, except we don't have copper. Copper is limited. So the amount of embrittlement is limited, and we've been through this extensively within ASTM and looking at embrittlement trends on high-copper versus low-copper material and we've got trend curves that track all that.

So from my perspective and, again, my personal perspective, I think the materials side is well dealt with if we know the composition of the material. Then we can get on to base how well it's done and how well it's demonstrated, and I'll leave that aside.

But I think, you know, to me, the bigger, the potential bigger differences between, say, an AP1000, to pick a new design plant, and the three much older plants that we analyzed come in the possible challenge events, the possible transients that could lead to --

MEMBER POWERS: Okay. Let me seek more of the Kirk definitive statement of all things done by the staff here. Suppose I told you that my new modern plant is going to be a load following plant?

MR. KIRK: A low?

MEMBER POWERS: Load following. That I will follow the load demands, rather than being a baseline plant. How does that change your analysis?

MR. KIRK: Well, I mean, obviously, it changes. Obviously. I would think it would change the frequency with which the transients occur or the likelihood that they would occur.

MEMBER RICCARDELLA: But on the other hand, you wouldn't accumulate doses rapidly.

MR. KIRK: That's true. I think there are a lot of things to consider there, which is why, which is why we didn't want to provide a blanket endorsement of things we hadn't analyzed.

MEMBER RICCARDELLA: But is there a similar restriction on using 61, the original PTS rule?

MR. KIRK: No, which is a little bit counter -- no, I don't want to use that word. I don't like --

MEMBER RICCARDELLA: So anybody, you know, if you build the vessel properly, you're going to be able to operate it under 61 and you wouldn't go here.

MR. KIRK: Yes. And it is a little bit

ironic that we haven't put a similar restriction on the use of the older rule for the newer plants, and the only reason for that remaining so is the perception that the older rule was more conservative. So if a licensee chooses to comply with the more conservative rule, from an embrittlement standpoint, it's up to them.

MEMBER STETKAR: Well, I mean, some of this is kind of interesting because I don't know anything about materials, but what I do know about newer plants, at least in licensing space, they're going to give you more large LOCAs because they're designed to blow you down, whether it's a pressurized water reactor or whether it's a boiling water reactor. I call it a large LOCA and everybody thinks of a pipe break. I think of de-pressurization valves. They're designed to get you down to low pressure really fast, and, therefore, the frequency of what you're now characterizing as the predominant thermal transient, that being a large primary blow-down, might be different for new plants, despite their materials differences, than the older designs. And that's strictly operational, you know, the way they're designed, at least in licensing space.

CHAIRMAN BALLINGER: And in a load following plant you get more fatigue cycles. I don't know what the accumulated dose would be. It would be lower on average, I suppose; but they'd be operating longer anyway.

MEMBER POWERS: Well, everything is cast in effective full-power year, so you take care of the dose issue. You do not take care of the more frequent transient issue.

MEMBER RICCARDELLA: Heat cycles.

CHAIRMAN BALLINGER: And that's something that's embedded in this rule, and I don't know how you handle that.

MEMBER RICCARDELLA: But you still are required to do an NDE every ten years, and so, presumably, if these cracks are growing, you're going to see them in those periodic inspections.

CHAIRMAN BALLINGER: The ten-year inspection would characterize the flaw distribution anyway.

MEMBER POWERS: Yes, and the trouble is you still have this component of the flaw distribution that counts for your ignorance and blindness.

CHAIRMAN BALLINGER: Yes, but they have

to be pretty big before they're problematic, like bigger than we've ever seen.

MEMBER RICCARDELLA: Yes, that kind of bigger.

CHAIRMAN BALLINGER: But, again, he's going to get to the requirement you have to validate your flaw distribution against your inspection results.

MR. KIRK: Right. And in any event, I mean, I think -- and I was going to apologize for not having all the answers, but these are hard questions. I mean, I think these hard questions point out why we included this provision in the rule that, if somebody wants to use this rule to apply to a newer plant, it's up to them to answer all these difficult questions.

MEMBER STETKAR: But do we know that 61 remains assumedly conservative?

MR. KIRK: What I can tell you, which is absolutely correct, is that the 50.61 embrittlement limits are more restrictive, more conservative, than the 50.61a limits. Whether that's -- what I can also tell you, which is factually correct, is that a detailed analysis of how much that greater conservatism of embrittlement would make up for possible increases in load, the staff hasn't done that analysis and I don't want to represent --

MEMBER POWERS: I mean, that's the inherent difficulty with 61 is that it's difficult to go in and say if I term the assumptions out how does the outcome change, and that was one of the objectives in "a" is to -- I mean, you never get rid of that problem but to reduce that problem down.

MEMBER RICCARDELLA: Presumably, the licensees, like for the AP1000, have done an evaluation on embrittlement before my time, so I haven't looked at them. But I assume that the staff has reviewed their analyses of reactor pressure vessel embrittlement, right?

MR. KIRK: I'm sorry. Where did you --

MEMBER RICCARDELLA: Well, an AP1000.

MR. KIRK: Oh, yes.

MEMBER RICCARDELLA: A new licensee come in and --

MEMBER POWERS: And I would not presume that things like using it as a load following plant had been examined at all.

CHAIRMAN BALLINGER: I think I remember

Gary saying, when I asked him last time how many plants would be forced into 61a for 60 years, and I think the number -- do I remember the number three?

MR. KIRK: Well, we'll get to that, but I'm going to have to object to your use of the word "force" because nobody is forced to use 50.61a.

MEMBER RICCARDELLA: Which effectively means shut it down.

CHAIRMAN BALLINGER: So then the question is what about 80 years?

MR. KIRK: Well, that's coming up, if I can get away from the load following plant question.

MR. WIDMAYER: Will be at 80 years. Never mind.

CHAIRMAN BALLINGER: Remember, just it's made good.

MR. KIRK: From the beginning, Dr. Powers is always asking questions that I can't answer, and this is the one for this briefing. Thank you.

MEMBER POWERS: You have no idea how much work it takes me to plan these questions.

MR. KIRK: No, that's good. I look forward to it. Okay. So I'm going to move on and try to get out of this.

CHAIRMAN BALLINGER: He's going to try to get out of here.

MEMBER STETKAR: They're still talking. Yes, that's okay.

MEMBER RICCARDELLA: I said the bigger question about load follow would be when existing plants decide to go to load follow because they're the ones that are going to be, you know, some of them might be pretty far out on the embrittlement curve. But, again, I think the ISI is what covers that.

MEMBER POWERS: I think it's cumulative you use each factor and certainly get them in trouble on load following.

MR. KIRK: Okay. We're going to try to talk about the non-controversial subject of surveillance data. So the goal of the statistical checks that are required by the alternate rule and are described by the reg guide draft guide is to ensure that the surveillance data for the particular plant being assessed is either well or conservatively represented by the embrittlement trend equation that was both used as a module in the probabilistic fracture mechanics calculations that provided the basis for the reference temperature screening criteria and also that's given in the rule.

So just schematically, the statistical tests are looking for three things. They're looking for how well does the embrittlement trend code represent the mean of the data, the slope or better to say the evolution of embrittlement with, I'm sorry, the evolution of transition temperature shift with embrittlement, and it's also looking for outliers in the data set.

Plants are required to perform these checks if they have three or more transition temperature shift values, which pretty much boils down to three or more capsules. They are required to consider all belt line plates, welds, and forgings for which data is available, not just for the so-called limiting welds. And they're also required to consider data from sister plants if it's available. And if you're not into the material geek lexicon, sister plant means that, say, Member Riccardella owns a plant that happens to have the same weld wire as my plant, so the data that he gets influences my plant and vice versa.

Being regulators, we've construed these

statistical tests only flagged underestimates. If the generic equations overestimate things, well, that's okay with us because an overestimate of transition temperature shift will be conservative. And as I've said, we're essentially doing three consistency checks to see that the plant-specific data here represented schematically by the green dots is well represented by the embrittlement trend curve represented by the red curve.

If the plant-specific data fail the test, well, then what next? Well, the general answer is the licensee, the general answer is the licensee needs to make a case to the director of NRR as to what that means and what they need to do about it. There were two cases that we saw to be simple enough that we could provide guidance, sort of a recipe if you will, in the regulatory guide. One is in the case of a mean test failure where the data are systematically above the embrittlement trend curve, one method that's acceptable to the staff is to simply add a factor on to the predicted curve to better represent your data. And the second case which we sometimes see -- excuse me -- is, oftentimes with the old surveillance capsule withdrawal schedule, you'll withdraw a capsule after the first or second operating cycle, so it's got very little dose on it. And in those cases, oftentimes you'll essentially be sampling the inherent material variability and you can see things like uncharacteristically higher low shifts or the often amazing case of increasing your upper shelf energy, not that that's considered here.

In any event, the guidance indicates that, if you happen to have an outlier at a very low fluence, less than 10 percent of that of your evaluation fluence, you could eliminate that data point from consideration.

If you don't happen to fall in these two categories, you're left doing your own engineering evaluation and trying to convince the NRR staff and director of NRR that you've done a good job.

The next regulatory guidance gets to the whole -- oh, sorry.

MEMBER RICCARDELLA: Are there any plants that are going to fall in this less than two capsules?

MR. KIRK: Yes, there are. I mean --

MEMBER RICCARDELLA: Eventually, they're going to get to three capsules, right?

MR. KIRK: Yes, yes. I mean, the -- yes, the requirements, the ASTME-185 requirements for -- I hesitate to say this a little bit because if you go back far enough in ASTME-185, there wasn't a specific number of capsules required. That was back in the 1960s, and I'm not sure that any plants that were originally licensed in the 1960s are still operating.

If they were licensed to a version of E-185 from the mid-70s and beyond, they would be required to have at least three capsules, and that would be for a low-shift material, if not more. So --

MEMBER RICCARDELLA: If you read the rule, it almost seems a little backwards that, well, if you don't have the data, if you don't have the data, then you don't need to evaluate whether the generic trend is applicable or not. I mean, that's kind of what you're saying.

MR. KIRK: Yes, that is what the rule says.

MEMBER RICCARDELLA: All right. But I'd assume anybody that's out there and approaching --

MR. KIRK: I'm not -- all I can say is

I'm not personally aware of any plant -- well, there's only one plant that's used this, and certainly that wasn't the case -- of any plant that's used this or that is considering using it that would fall into the category of not having at least three capsules pulled by the time they're considering using it.

MEMBER RICCARDELLA: That's what I would assume.

MR. KIRK: It was really a condition put in. And you're right, it doesn't fully make sense, but it was just a condition put in to make sure that everything was covered.

Okay. Getting to the regulatory guidance on in-service inspection, the reason for the requirement is quite simply stated. As I said, you know, you go back to the sort of basic fracture mechanics equation that driving force equals stress times square root of pi times crack size. So, obviously, the crack sizes that we have used in the analysis to set the screening limits are really important to what those screen limits wound up being. So we wanted to include a check to make sure that the flaws or the indications that are found in the plant are well represented by that flaw population that was assumed in making those limits. And that's the intent of what's going on here.

So the examination requirements. We require a qualified examination be performed in accordance with ASME Code, Section XI, Mandatory Appendix VIII. And we also require, and this goes beyond as required by the code, a requirement that's, I'll say, unique to this rule is a verification that any axial flaws found at greater than 0.075 inch through-wall extent at the clad interface don't open to the inside RPV service. So what we want to do, the intent of this is the recognition that a surface-breaking flaw to the ID would be significant, so we want the licensees to affirm that they don't exist.

An optional thing that licensees could pursue if they want to is they can account for NDE uncertainty. So if you, say if you went through and tried to meet the flaw tables in the rule using your straight-out NDE results from a Section XI, Appendix VIII exam and you didn't meet the requirements, if you go through and account for NDE uncertainty, it may be possible that you then satisfy the tables because the at least now current

NDE techniques tend to oversize smaller flaws, which tends to characterize them more conservatively than they need to be. All I can say is in the one application that's gone through, that being the Palisades application, that optional path did not need to be followed.

MEMBER SKILLMAN: Mark, before you change that slide, what change, if any, to the NDE equipment has been obligated by an applicant that would want to use 50.61a?

MR. KIRK: Well, there's no change here because there is, as Pete's pointed out already, they're already doing the ASME exam. I could just speak to the one that's done it because I was there watching the exam. In the case of Palisades, they put on their inspection sled also transducers to do any current at the same time as they were doing the regular Section XI, Appendix VIII exam because they knew going in that they were doing, the one point of doing this inspection was to provide input to 50.61a. So they knew they would need to verify -- what the rule says is that they need to verify that axial flaws that I'll say are close to the cladding, the rule doesn't use that language, but are close to the cladding or not surface connected, the NDE inspector I talked to said, yes, it's just easier for us, the sled is in the vessel, I have to dose people up to go in and change this out, so we've just put eddy current probes on the sled, as well, and so we're going to eddy current the whole inside. Every indication they found, because, of course, they do the analysis offline later, basically every indication they found they also eddy-currented, if that's the right way to say it, a patch on the ID in the vicinity of that so that they would have the data later that they needed.

That's the only plant that's done it. So that's what they did.

CHAIRMAN BALLINGER: So that -- I'm trying to remember now. Did that help get rid of these ghost kind of indications that looked like flaws that weren't? If I recall. Maybe I'm just not remembering correctly.

MR. KIRK: I don't, I couldn't comment on that. I don't know.

MEMBER RICCARDELLA: I think the idea is the flaws are much worse if they penetrate for this analysis than if they penetrate the cladding, and the UT doesn't really inspect the cladding. They inspect the base metal, so, this way, they can say, well, if I had an indication, I also inspected the ID surface of the cladding and I'm confident that there's no surface breaking flaw there.

CHAIRMAN BALLINGER: I thought there were some plants that had indications that turned out not to be indications.

MR. KIRK: Oh, I'm sure there are.

CHAIRMAN BALLINGER: But it's a problem here because of the flaw size distribution requirement.

MR. KIRK: Okay. I think this gets into a little more detail. We're looking for flaws or -- I'm sorry I'm not a good NDE guy. Indications. We're looking for indications in a number of categories, and I'll work up from the bottom from the least risk significant to the most. Embedded indications beyond 3/8t from the ID, embedded between one inch and 3/8t from the ID, embedded within one inch of the inner-diameter and surface connected. And the reason why the risk significance goes as indicated by the arrow is simply that this is a thermally-driven event. So the tensile stresses are nearest the ID, and so you want to be looking for those because they're the ones that are driving the risk.

In terms of the guidance in the regulatory guide and the requirements of the rule for how flaws in these different bins are assessed -- I'm back to flaws again. Sorry. For surface, if you found a surface-connected flaw, a flaw that's surface connected to the ID, you would have to do a plant flaw-specific assessment of the through-wall cracking frequency because that's beyond the scope of what was systematically considered in the tech basis calculations.

If they're embedded within an inch of the inner diameter, that's where you use the flaw tables. If they're between an inch and 3/8t, that's where you use ASME Section XII code, and beyond 3/8t, again, you're deferring to the code requirements.

So the PTS-specific requirements that go beyond the code really come from in these first two categories of the surface-connected flaw and embedded flaws within one inch of the inner diameter of the vessel. All the rest is the same as for any vessel complying with ASME Section XI.

This is probably more detailed than we need here. We recognize that sometimes the language that gets into the Code of Federal

Regulations is a little bit difficult to follow for engineers. It's probably very easy for lawyers. So Gary and I turned that language into a flow chart with references to the different parts, the different invoking languages of the code.

But this is essentially walking you through, and this is part of the reg guide now or will be part of the reg guide. You do your ASME Section XI inspection. You're asked do you have surface-connected flaws. You go through the flaw table. You account for NDE uncertainty, and you eventually come to either the conclusion that you need to do a plant-specific assessment, that you can't use directly the provisions of the alternate rule or the alternate rule is applicable for your use. And the reg guide steps you through it.

Again, I should just emphasize there's nothing on this flow chart that's in any way different from what's in the rule. The flow chart is in the reg guide, and it's just an attempt to explain more clearly to engineers what the provisions of the rule are.

MEMBER SKILLMAN: Mark, if the inspection finds an indication and further NDE demonstrate that there really is a connected crack of significance, does that automatically trigger a repair?

MR. KIRK: No. Well, I have to defer to people that know about the code. I don't think size of indications that we're talking about here you would be forced into a repair by the code, and certainly the alternate PTS rule doesn't force you into a repair. The alternate PTS rule would force you into a plant-specific through-wall cracking frequency evaluation.

MEMBER SKILLMAN: Would that enhance the next inspection interval into a five year instead of a ten?

MEMBER RICCARDELLA: Yes, what happens is, in the code parlance, these are the standards for evaluation, which are just a set of tables you go and look at. If you exceed those tables, you have the option to repair or do a detailed fracture mechanics evaluation. And if you do do the detailed fracture mechanics evaluation, then you do get kicked into more frequent exams.

MEMBER SKILLMAN: Thank you.

MR. KIRK: Okay. And also there's a part of the -- excuse me -- there's a part of the alternate rule that talks about alternate embrittlement screening criteria, meaning alternate to the reference temperature tables in the alternate rule. Too many alternates. Sorry.

So why are they needed? Paragraph (c)(3) of 50.61a allows for a plant-specific analysis just by operation if the RT max values exceed the PTS screening criteria. We've provided here one method, there are certainly other ways to do this, that a plant could demonstrate that, and that's simply to say that the reference temperature screening criteria that are in the table are based on bounding curve fits to the PFM results, which you saw earlier.

And what you get, as I indicated before, the screening limits are determined by saying -- and the bounds aren't shown here. That's a bad slight on my part. But if you add up the three bounding curves, they should be limited to 10 to the minus 6. What that gets you is this three-dimensional surface that's almost a box but not quite. It's a box with rounded edges.

In order to easily put that into a table that could be put in a federal regulation, we had to simplify the box somewhat, which meant that we had to say that the reference temperature max for the circ weld, because we knew that circ welds would hardly ever be limiting, wouldn't go above a certain value. So we essentially set the screening criteria for the circ weld to be 10 to the minus 8 just to make the plate and axial weld screening easier in a simple table look-up format. We felt that was a reasonable thing to do simply because we didn't know at the time of any plants that were circ weld limited or would be circ weld limited in the foreseeable future. However, we wanted to provide this alternate means, should a circ weld plant experience high embrittlement, that they could be then held to a 10 to the minus 6 screening criteria, rather than a 10 to the minus 8, which is inherent to the tables. That's really all this is doing. Going through this set of equations is the equivalent to the technical basis information on which the reference temperature values in the table in the alternate rule were based.

Now we get to the question I know Ron has been wanting to ask, which is potential future use of 50.61a, and I think I should emphasize here "potential" because foretelling the future is not very easy and if I could do that I would have hit the lotto a long time ago.

MEMBER POWERS: A famous quote, "Prognostication is difficult, especially about the future."

MR. KIRK: Yes, it is.

CHAIRMAN BALLINGER: That's got to be Yogi Berra.

MEMBER POWERS: I think it was Mark Twain.

MR. KIRK: I think I should probably quote Yogi Berra in preference to more my style. Anyway, this is just a reminder of what we told you in October 2014, in case you forgot. These were the plants that were then on the list. That's changed somewhat, as I'll reflect here, and we'll just go down it.

And now responding to the question that Ron had asked us before the meeting, I talked about potentials 50.61a use both during license renewal, which is NRC code for within 60 years, or during subsequent license renewal, meaning 60 to 80 years.

So Beaver Valley Unit 1, the last time we talked, the plate in Beaver Valley Unit 1 had been projected to exceed the 50.61 screening criteria before the end of their license renewal period; and, therefore, they had made an application to use 50.61a in 2013. However, after they made that application and while the staff was still conducting its review, they found data on their limiting materials that they weren't aware that they had, and that allowed them to both recalculate their embrittlement trends -- they got a new chemistry factor, essentially, using Reg Guide 199 -- and also get a better estimate of their underrated RTNDT. Based on those two improvements to their data, they found out that they were no longer projecting that they would exceed the 50.61 screening criteria and so withdrew the application.

So based on a conventional 50.61 analysis, Beaver Valley is now showing that it's not projected to exceed those screening limits within license renewal, so use of 50.61a during license renewal is unlikely. It's possible during subsequent license renewal, but I think the thing I'm going to say on the next slide is, right now, the staff is not aware of any plant that has short-term plans to use 50.61a. These are just ones that could be coming up.

Diablo Canyon Unit 1, axial weld is projected to exceed the 50.61 screening criteria before the end of license renewal. And so, you know, definitely possible that they could use it, but there are other things they could do we'll talk about on the next slide.

Fort Calhoun. So I'm focusing here on plants that are known to be high embrittlement. Axial weld is projected to have an RTPTS of 268 at end of license renewal, so they'll remain compliant with 50.61 based on current projections by two degrees. Two degrees is important. So they're not going to use it during license renewal. They could possibly use it during subsequent license renewal.

Palisades, we already know the answer. They use it during license renewal. I'm not aware that Palisades is pursuing subsequent license renewal, but if they did they might use it again.

Point Beach Unit 2 and Three Mile Island I'd like to talk about together. They're both plants that are known to have reference temperatures approaching the RTPTS screening limits of 50.61. However, they're both plants that are covered by the Babcock and Wilcox 2308 approach, which essentially uses master curve data, true fracture toughness data to reset the initial RTNDT. That's an approach that's been pursued for pretty much all Babcock and Wilcox fabricated plants that had lineated welds. It's used routinely, and that's why those two high-embrittlement plants -- by high embrittlement, I mean approaching the 50.61 screening criteria -- have not and probably will not use 10 CFR 50.61a because they've got another means that worked well for them.

Finally on the list, Salem Unit 1. Its axial weld is projected to have an RTPTS of 267, three degrees less, at the end of license renewal. So they would not be, see no reason why they would use 50.61a during license renewal, but they could possibly use it during subsequent license renewal.

MEMBER RICCARDELLA: Did you skip over Indian Point in Unit 3?

MR. KIRK: I think I did. Yes, so we see -- sorry about that. We see possible use by Indian Point Unit 3, before the end of license renewal, because they're projected to exceed the, the 50.61 limit before 2025. I didn't mean to skip them.

That all said, I mean, the two dates on here are 2025 and 2033, so a decade to a decade-and-a-half from now, which means it might be only my colleague, Matt Gordon, who's left here to talk about it. I'll be retired.

So no licensees have indicated any short-term plans, by short-term, I mean in the, in the next three to five years, to use 50.61a. Just a disclaimer, the list on the previous page may not include all plans that are considering the use, it's a due diligence effort.

And also should point out, the plans may elect to use 50.61a, not for compliance reasons, but for economic reasons. Say, somebody was considering buying a new steam generator and wanted to make, wanted to get as many things off the regulatory problem list, as they could, they might decide to use 50.61a and we would have no way of knowing, before they, they brought that case to us, so clearly that's not included.

And also, just a reminder, and this right-most column is nothing other than a statement of the facts of our current regulatory structure is that, plants have options, other than 50.61a and other than annealing, to address and manage embrittlement.

They have various physical options, fuel management, changing operational characteristics and annealing. They have data options. They can look more to plant-specific surveillance data, they can get Master Curve data, using the BAW-2308 approach.

And, I should also point out that there is now ongoing, within the industry, renewed interest in pursuing Master Curve and direct fracture toughness measurements being pursued by the PWR Owners Group and also going through ASME Code and the guise of a revised version of ASME Code Case N-830.

So Master Curve use, in general, beyond the BNW plants, has not been, I'll say, pursued in earnest for about the last decade, but within the last year to two years there's been renewed interest in that, so a number of plants are looking at that, again, no plant-specific applications, but general industry study programs and work within the Code to enable that type of analysis.

And, of course, there are always analytical options, meaning plant-specific PRA and/or PFM, like we talked about before, to demonstrate compliance with, to demonstrate vessel safety.

MEMBER POWERS: I -- my presumption is that you are relatively confident in the probabilistic fracture mechanics and you have indicated a confidence in the knowledge and material properties, when a licensee comes to you with a new approach, at what point, in what area would you require experimental validation of his approach?

MR. KIRK: I thought I'd gotten rid of that question. Experiment of validation of any aspect, or --

MEMBER POWERS: Some aspect. I mean, I get the feeling that you would not require it for the probabilistic fracture mechanics, which in my mind, is little more than witchcraft. Oh that was just for you. And you've indicated a confidence in understanding material properties, so I'm sitting here saying, what, what would provoke into saying, gee, I really need to see some experiments here, to, to give me confidence in this, this alternate approach?

MR. KIRK: I mean, I find it, I find it really personally hard to speculate. I mean, getting into any of these reviews, and, you know, I should point out, you know, I'm not, I don't really work for the regulatory part of the agency, I --

MEMBER POWERS: And that --

MR. KIRK: -- I work for the research part.

MEMBER POWERS: We're just holding you accountable for --

MR. KIRK: Thank you.

MEMBER POWERS: -- speaking for that person.

MR. KIRK: I appreciate it. And the guy that's left up here. I think it really depends on, and I'm -- you know, this is an evasive answer and I'll just label it, as such. It really depends upon the specifics of the case at hand and how strong, strongly the case has been supported.

MEMBER POWERS: Well, where would you, where would you look most diligently?

MR. KIRK: Well, again, the loads full-size embrittlement. And, and, and, and, I think, also, a lot of us depends on how road full-size embrittlement and that's axiomatic, but it depends on how close somebody is to some perceived regulatory limit.

MEMBER POWERS: Well, I mean, we presume that he is --

MR. KIRK: Okay, I mean, --

MEMBER POWERS: -- comes to you with a

new technique, because he's getting very, very close, if not exceeding, --

MR. KIRK: Yes. Well, let's get back to the, if, if you had a plant, if you had a new plant that we hadn't analyzed yet, and there was, you know, concern from staff experienced, you know, in the operational side that the plant operational characteristics wouldn't lead to the same challenge events, as we had analyzed here, I think that would be a, you know, a ripe area for, you know, for study.

And, and, you know, I'll throw a stone at materials, while I'm at it. If there was something unusual in the surveillance data, if you had -- okay, I'll give you a good example that, fortunately, is not in this country.

The Genkai Power Plant in, in Japan, pulled its four surveillance capsule, some years ago, and while the previous three surveillance capsules had been, pretty much, following the generic trend, it had an out wire, not at the low fluency end, but at the high fluency end, and in the case of Japan, that provoked an extremely detailed study getting into more measurements, more mechanical property measurements, diagnosis of the mechanical property measurements, more micro-structural property measurements, to try to understand the basis for that one out wire.

So I think, you know, you got to, you got to look for something, I'll say, strange, unusual, outside of your experience that doesn't seem quite right, before, as a regulator, or as an advisor to the regulator, you say, and maybe you should bring me something more. I'm struggling, because I'm not good with hypotheticals, so I have to, I have to think of things that have actually happened. So I think those, you know, those would be good categories for, for more, you know, more detailed inquiry.

MEMBER POWERS: Oh I understand that what I'm thinking about is the codicil in the guidance that says these are the things that go beyond the scope of our experience, and when you encounter them, please don't, please come talk to us, before you rely on this guidance.

MR. KIRK: Yes. Right, but we haven't, and I think that's, that's a prudent thing to say, we haven't then prejudged exactly where that conversation will go.

MEMBER POWERS: Yes, and --

MR. KIRK: Yes.

MEMBER POWERS: -- but, while I'm interested in where this guidance -- you would not be confident if somebody was using this guidance.

MR. KIRK: No. I mean, I think that's, and again, sort of statistics 101 when you get outside of your experience, you start looking for more evidence --

MEMBER POWERS: The --

MR. KIRK: -- to backup.

MEMBER POWERS: -- the trouble is that this guidance will be used by people who use it, as a prescription, and so it's, it's incumbent upon you with a great deal of experience to communicate them, not only how to use it, but when not to use it.

MR. KIRK: Yes. And are you suggesting, or asking, if we've done that well-enough to --

MEMBER POWERS: I am.

MR. KIRK: -- to say when it's not a prescription?

MEMBER POWERS: I am.

MR. KIRK: I mean, --

MEMBER POWERS: I'm asking you to think

about it for a little bit.

MR. KIRK: Okay. We should think about that.

MEMBER POWERS: I think that's, I think that's going to be increasingly important, as you think about migrating to New Hampshire.

CHAIRMAN BALLINGER: You might force him to migrate to New Hampshire early.

MR. KIRK: The --

MEMBER POWERS: I've tried that for years and failed miserably, so --

(Simultaneous speaking.)

MR. KIRK: The part of New Hampshire I'm considering migrating to have electric rates that almost doubled when Vermont and Yankee closed.

MEMBER POWERS: Yes.

MR. KIRK: So --

MEMBER POWERS: Very foolish on your part.

MR. KIRK: Now I'm getting my exercise cutting wood.

MEMBER POWERS: Helping the environment, no doubt.

MR. KIRK: No doubt.

MEMBER SKILLMAN: Mark, let me ask two

questions. They're similar to what Dana just asked, but in my own work for preparation for today's meeting, I've written them down, so I think this is the best time to ask them.

How do you handle the variability in chemistry? And here's why I'm asking the question. Like Dana said, this is a very prescriptive approach. Equations five, six, and seven, guide a user to take action to develop a delta T --

MR. KIRK: Right.

MEMBER SKILLMAN: -- integer. And the ingredients in those calculations include copper content, effective copper content, nickel content, manganese content and phosphorus content, in the, in the other comments from the public and others, it says, these are the soft metals that's giving us a problem here. How do you handle, or how do you anticipate a licensee is going to handle uncertainties in those --

MR. KIRK: Yes.

MEMBER SKILLMAN: -- ingredient concentrations in their plates and their foragings?

MR. KIRK: Well in that case, we have attempted, and I think done as good a job, as possible, based on the information we've got, to handle it for them and that the, the uncertainties in those, in the chemistry inputs were sampled, as part of the favor analyses.

Because, it's very, it would be very unusual for a licensee to say, have enough measurements of any of these copper, nickel, what have you, to form a statistical distribution.

So in the favor analyses, we took the, and that's actually documented in the appendix of NUREG-1807, I think, we went out and looked for data that was available where people had done repeated measurements, developed statistical distributions to represent them, and that was sampled within the PFM analyses that then gave rise to the reference temperature limits.

So I would say that that part of the uncertainty is explicitly covered by the reference temperature limits, themselves, and for that reason, we ask the licensees only to come in with so called best estimate values of each of those variables, which would be the same type of input that we look for, for 50.61 applications, for PT limits analysis and, and so on.

MEMBER SKILLMAN: Okay. Let me ask another one, similar-type question. And I draw this from almost 45 years ago, the, those of us who were doing the systems in the ACCS analysis in Babcock were right next to the reactor vessel and the internals people, so we heard them struggling with where to place the surveillance vestment holder, tubes and the geometry and the concerns about the fluency, too, the SSHTs and to the specimens, surveillance specimen holder tubes and the specimens.

And this has to do with the uncertainty of the fluency on the specimen. How do you address in this, in this set of equations, the variability, or the uncertainty in the absorbed dose to the specimen, itself?

MR. KIRK: Again, that's, that's the same answer. That's an uncertainty that we sampled within the original calculations of -- well, the thought, at the time, much like the chemistry, is it wasn't realistic to ask somebody to do that on a plant-specific basis, so we included that uncertainty in the basis calculation, so it's reflected in the referenced temperature limits. And again, we just look for the input of the best estimate fluency for the location on the ID of the, of the various vessel materials.

MEMBER SKILLMAN: Okay. Final question. In Table 1, which is on Page 6 of the Guide, the terms include neutron fluency and effective neutron fluency and copper content and effective copper content. Could you explain what --

MR. KIRK: Yes.

MEMBER SKILLMAN: -- effective means, in the --

MR. KIRK: Yes, those are, and in, you know, now that I see that, I'm sorry they're there. I mean, those are terms that are used in the, in the embrittlement equations that is Equations five, six, and seven, in the guide and corresponding equations in the Rule, itself.

But, be that as it may, those are values that are fitting parameters, if you will, --

MEMBER SKILLMAN: I was wondering if they were, they were averages, or means, or --

MR. KIRK: No, they're --

MEMBER SKILLMAN: -- aggregated --

MR. KIRK: -- they're just --

MEMBER SKILLMAN: -- aggregated values from some other --

MR. KIRK: No they're -- well, in the

case, and maybe the easiest one to explain is -- well I can explain them both. Effective copper content reflects the fact that, above a certain limit, copper is ineffective, as an embrittlement element, and so it caps the copper at a, at a copper max value, but that's taken care of in the equation.

The effective fluency reflects the fact that, at least, in terms of this embrittlement equation, the neutron flux has a second order effect on the degree of embrittlement, and again that's accounted for in the equation.

So those aren't, you know, again, looking at this again, those aren't direct inputs to the equation, they're calculated from other inputs, so I think it would have probably been clearer to, to take them out, but they're not something that's separate, you input copper, nickel, phosphorus, manganese, fluency and temperature and everything else is calculated.

MEMBER SKILLMAN: Okay. Mark, thank you.

MR. KIRK: Okay. Thank you, sir.

MEMBER SKILLMAN: Thanks.

CHAIRMAN BALLINGER: Is this a

convenient point we're going to shift to another --

MR. KIRK: I think it is, yes.

CHAIRMAN BALLINGER: All right. I have one question before we, before we do that and it's probably a dumb one, but on Page 7 --

MR. KIRK: Of the Guide?

CHAIRMAN BALLINGER: -- of the Guide, Paragraph B-I.

MR. KIRK: Yes.

CHAIRMAN BALLINGER: Can you tell me what that means?

MR. KIRK: Oh no. This seems, to me, to be one of those that we might have revised, because it was unclear.

CHAIRMAN BALLINGER: Okay.

MR. KIRK: What it's trying to say, we talked about earlier, is that, you need three measurements of Delta T-33 transition temperature shift values at three different fluency values, in order to do the surveillance check. If you don't have, at least, that, you just use the equation.

CHAIRMAN BALLINGER: Right. I understand that part.

MR. KIRK: It --

CHAIRMAN BALLINGER: I understand what

you said and I understand what it --

MR. KIRK: Good.

CHAIRMAN BALLINGER: -- read before, but for the life of me --

MR. KIRK: Yes, well I, I --

CHAIRMAN BALLINGER: -- I don't understand what that means.

MR. KIRK: Well I have the original, unmarked-up version. I'll have to check. I think that was one where many people made the comment of, what are you trying to say?

CHAIRMAN BALLINGER: Okay.

MR. KIRK: So hopefully we've clarified that, but I can, I can check that.

CHAIRMAN BALLINGER: Okay. Does anybody around the table have any questions? But, I think, we're going to, I'm going to propose that we take a 15-minute break now.

MEMBER REMPE: Right now we're going to the closed session.

CHAIRMAN BALLINGER: Oh, we're going to a closed session, after this, right?

MR. WIDMAYER: Right.

CHAIRMAN BALLINGER: Okay, so you're right. Are there any comments from anybody in the room? Derek, do we need to get the line open?

MR. WIDMAYER: There is, yes, we need to get the line open.

CHAIRMAN BALLINGER: Can we get the line open?

MR. WIDMAYER: It should be one person.

CHAIRMAN BALLINGER: One person. Yes, I must have read that, that little paragraph a dozen times, could not figure out --

MR. KIRK: Yes.

CHAIRMAN BALLINGER: -- what we're saying.

MR. WIDMAYER: Okay, it's on, it's open.

CHAIRMAN BALLINGER: Yes are there, I don't hear any crackling, or popping, either.

MR. WIDMAYER: Try.

CHAIRMAN BALLINGER: Try? Is there anybody out there on the line?

MR. LEWIS: Marvin Lewis, member of the public.

CHAIRMAN BALLINGER: Good afternoon, Marvin.

MR. LEWIS: Thank you. Look, I'm just wondering, you know, we've use justifications to forget about outliers that, sort of, go against the grain, of course outliers go against the grain, that's why they're outliers, right?

My problem is this, are you forgetting a lot of experience, not only in the U.S., but outside the United States that might show what you're, show that there's a problem there that you're not looking at, like, for instance, Belgian reactors that has shown a lot of micro cracks.

And I'm wondering, you did reference a couple of other ones, and I'm just wondering if there is a trend somewhere that you're missing on, on this toughness subject?

I'm, I'm not saying there is, I'm just wondering, because I, you know, you're using justification here, justification there, and I'm just wondering if there is a trend that you're just getting around with justifications? Thank you.

CHAIRMAN BALLINGER: Thank you. Are there any other folks out there, who would like to make a comment?

(No response.)

CHAIRMAN BALLINGER: Hearing none, can we close the line? Okay, so I think we can take now a 15-minute recess, until just before quarter after.

(Whereupon, the meeting in the above-entitled matter was concluded at 2:57 p.m.)

United States Nuclear Regulatory Commission
Protecting People and the Environment

Advisory Committee on Reactor Safeguards Materials Subcommittee Meeting

review of

→ Draft Reg Guide (DG-1299 / RG 1.230) ←
→ Draft Tech Basis Document (NUREG-2163) ←

[*both concerning the Alternate PTS Rule (10 CFR 50.61a)*]

Mark Kirk, Senior Materials Engineer

Office of Nuclear Regulatory Research
Component Integrity Branch

Tuesday May 3, 2016
NRC Headquarters
Rockville, MD

Presentation Overview

United States Nuclear Regulatory Commission
Protecting People and the Environment

- Alternate PTS rule (10 CFR 50.61a) development & background

- PTS Rule Regulatory Guide
  - Reg guide process development summary & current status
  - Overview of tech basis & reg guide

- Possible future use of 10 CFR 50.61a & RG 1.230

- Public Comments on reg guide and tech basis
  - Summary of responses
  - Summary of changes to RG & NUREG
  - Path forward / next steps

- **NRC staff request of ACRS**
  - **Memo to NRC/RES approving RG & NUREG, or**
  - **Letter to EDO objecting to RG & NUREG**

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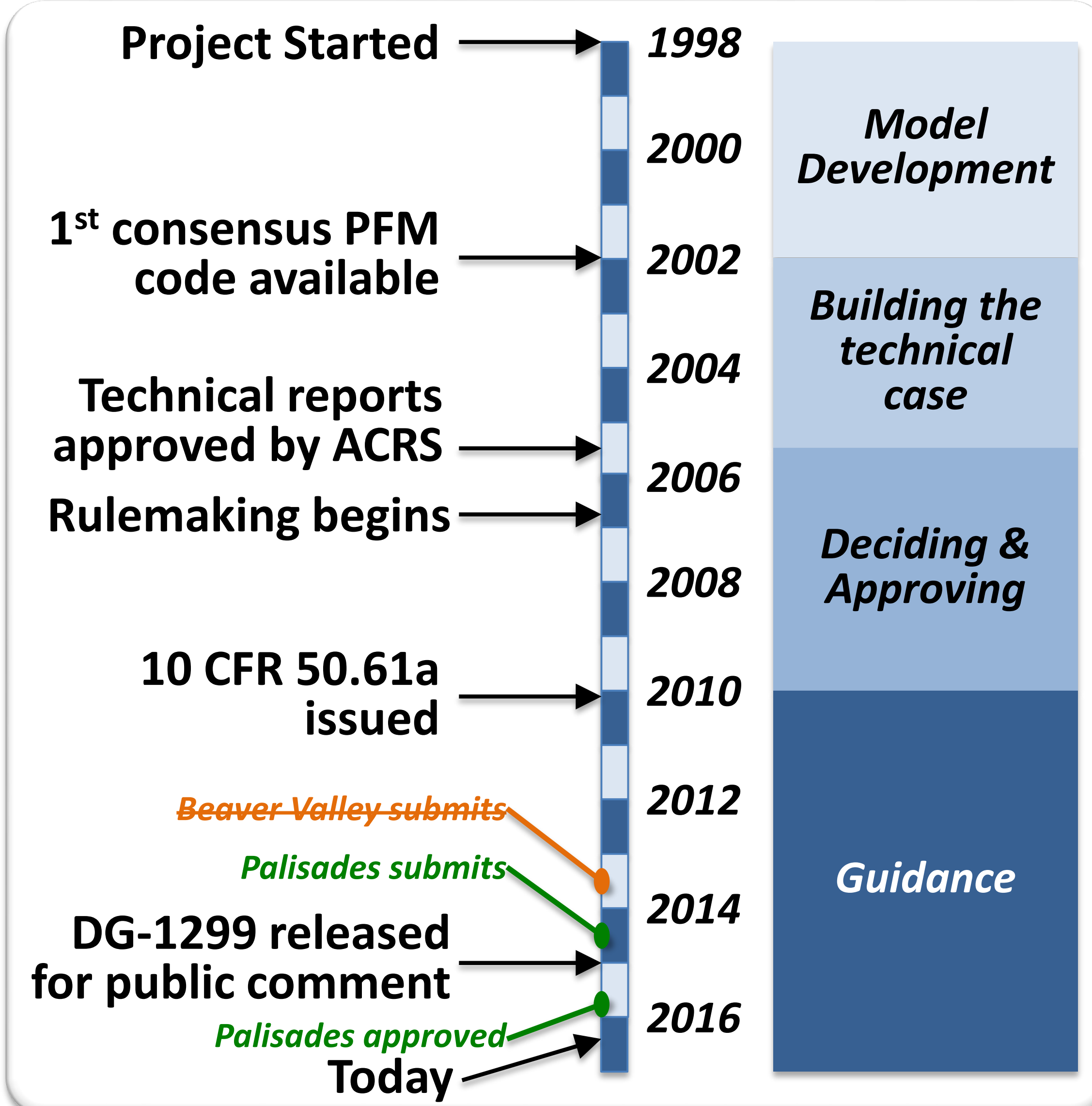
Overall Alt-PTS Timeline

Simplified

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

- **Development, approval, & current use spans nearly 2 decades**
- **Includes extensive reviews & opportunities to comment**
  - ACRS
  - External review panel
  - Internal NRC
  - Public meetings
  - Public comments
- **Current task: issuing regulatory guidance**



BACKGROUND

What is 10 CFR 50.61a?

Why was it developed?

(Chapter 1 of NUREG-2163)

The Path to 10 CFR 50.61a

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

- Motivations for alternate rule development
- Overall approach
- Key results
- The Alternate PTS Rule (10 CFR 50.61a)

Technical Motivations

- **PRA**
  - Use of latest PRA/HRA data
  - More refined binning
  - Operator action credited
  - Acts of commission considered
  - External events considered
  - Medium and large-break LOCAs considered
- **TH**
  - Many more TH sequences modeled
  - TH code improved

Developments since the 1980s suggested the overall conservatism of the rule

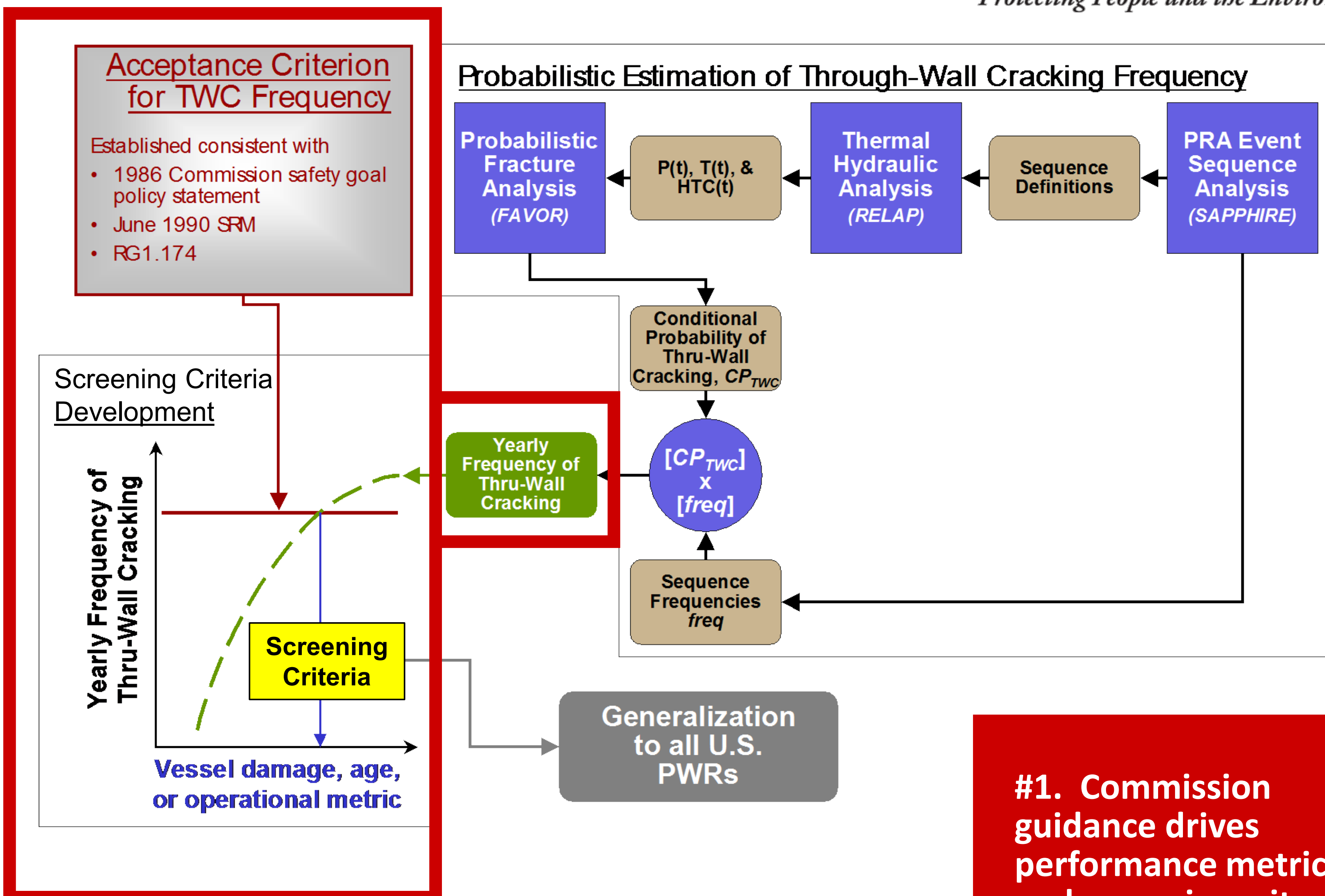
- **PFM**
  - Significant conservative bias in toughness model removed
  - Spatial variation in fluence recognized
  - Most flaws now embedded rather than on the surface, also smaller
  - Material region dependent embrittlement props.
  - Non-conservatisms in arrest and embrittlement models removed

Regulatory Motivations

- **Produces unnecessary burden**
  - Technical improvements suggest strongly that current RT_{NDT} screening criteria of 300 °F and 270 °F are more conservative than needed to maintain safety.
- **Does not necessarily increase overall plant safety**
  - Focus on unnecessarily conservative RT_{NDT} screening criteria can divert resources from other more risk-significant matters.
- **Plant-specific analysis not a practical option**
  - Difficult to perform and review. Completeness and success criteria unclear.
- **Creates an artificial impediment to license renewal**
  - Unnecessarily conservative RT_{NDT} screening criteria alter perception of the safe operational life of a nuclear power plant.

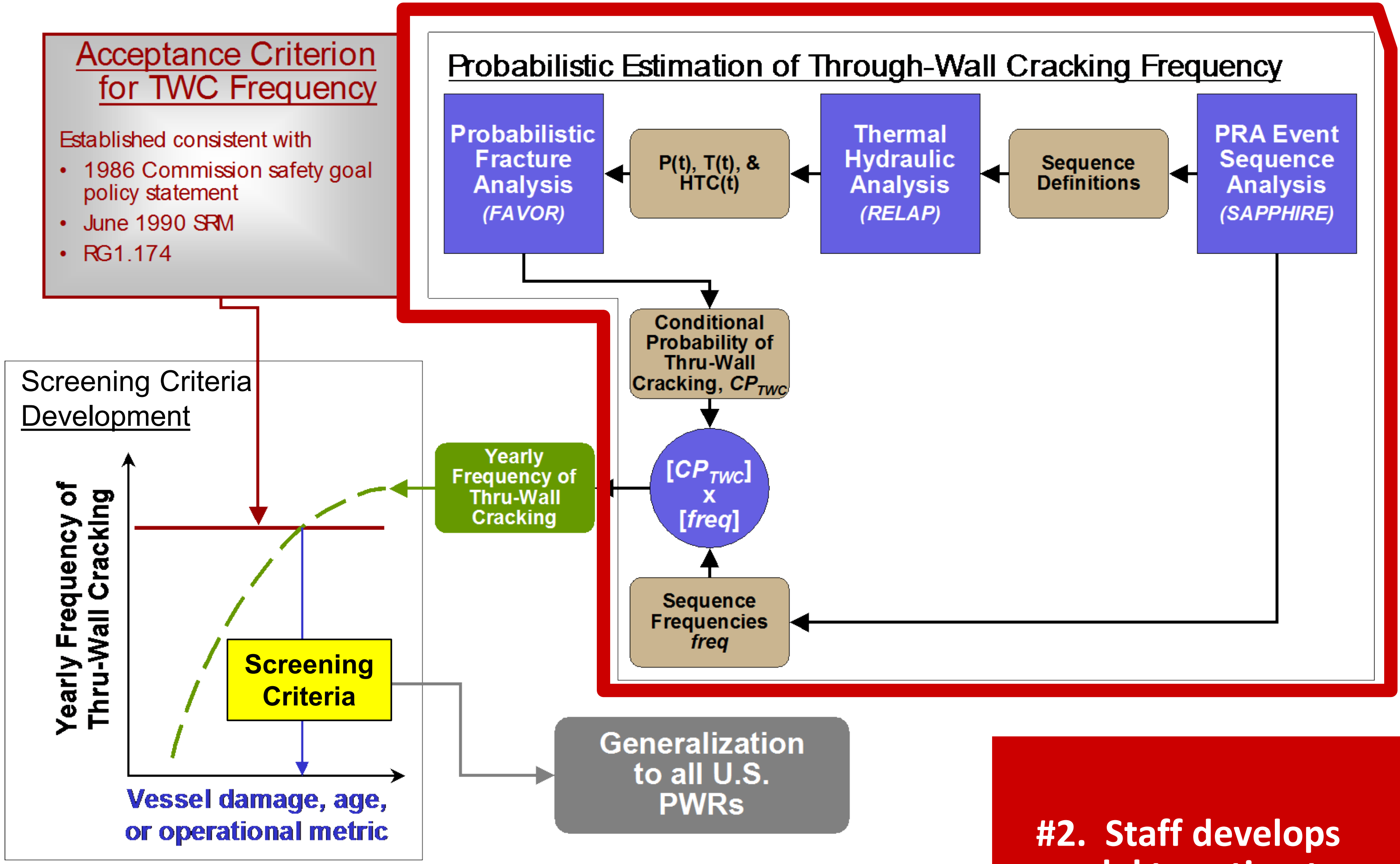
→ ***Causes work that produces no real benefit*** ←

PTS Project – Overall Approach



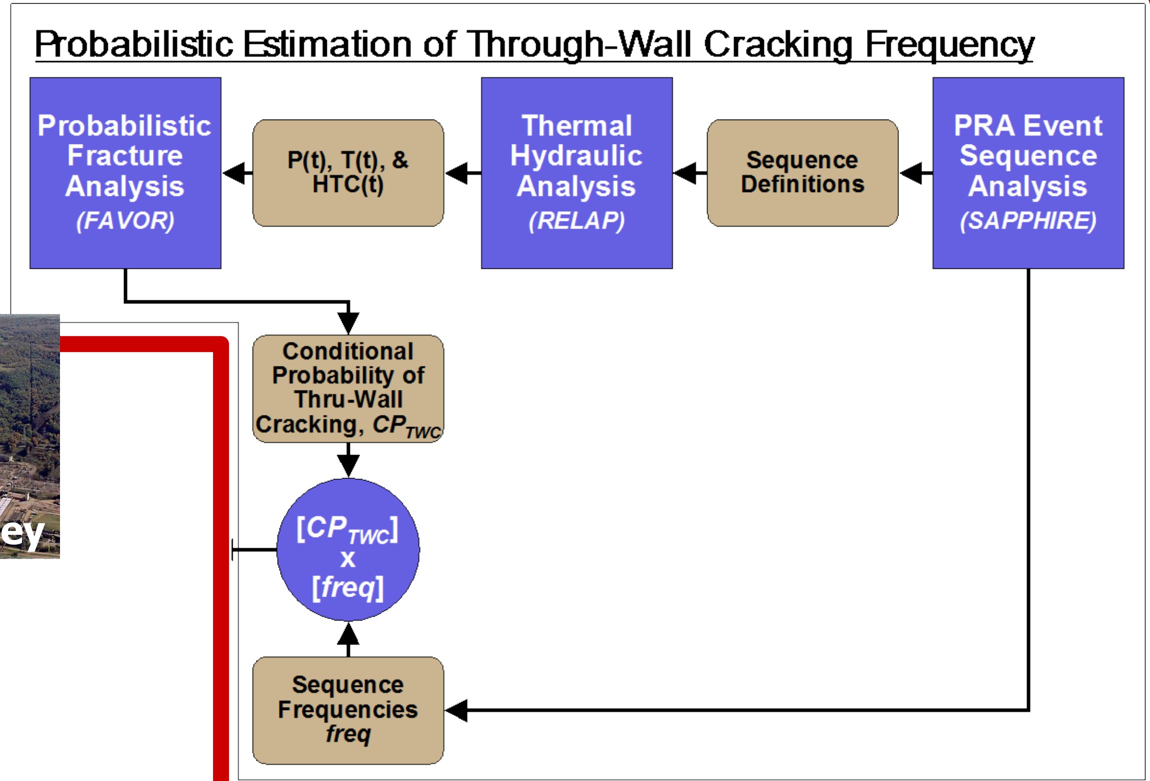
#1. Commission guidance drives performance metric, and screening criteria.

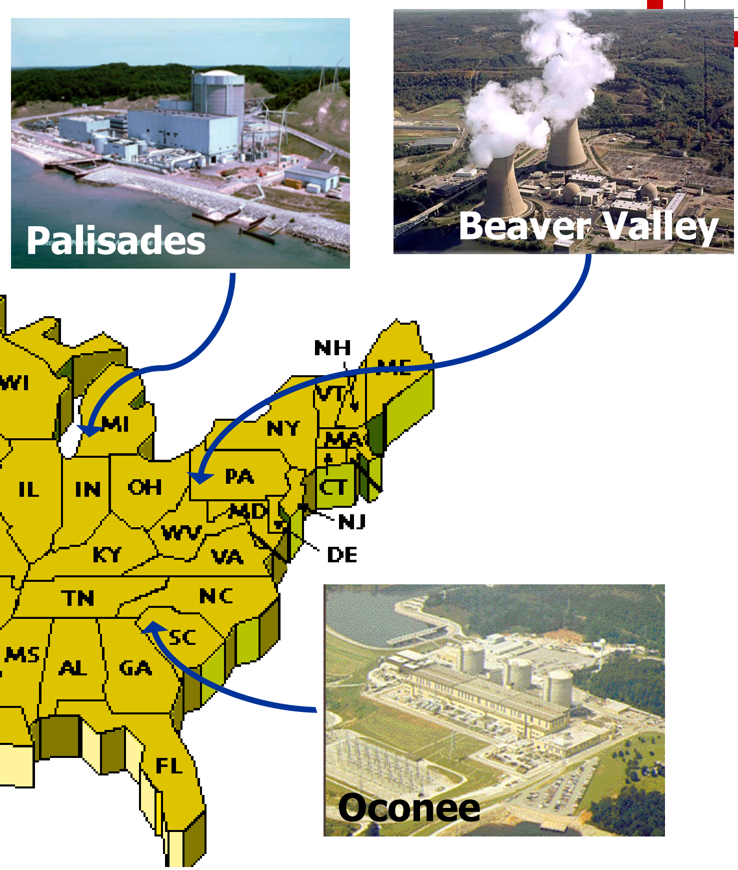
PTS Project – Overall Approach



#2. Staff develops model to estimate performance metric.

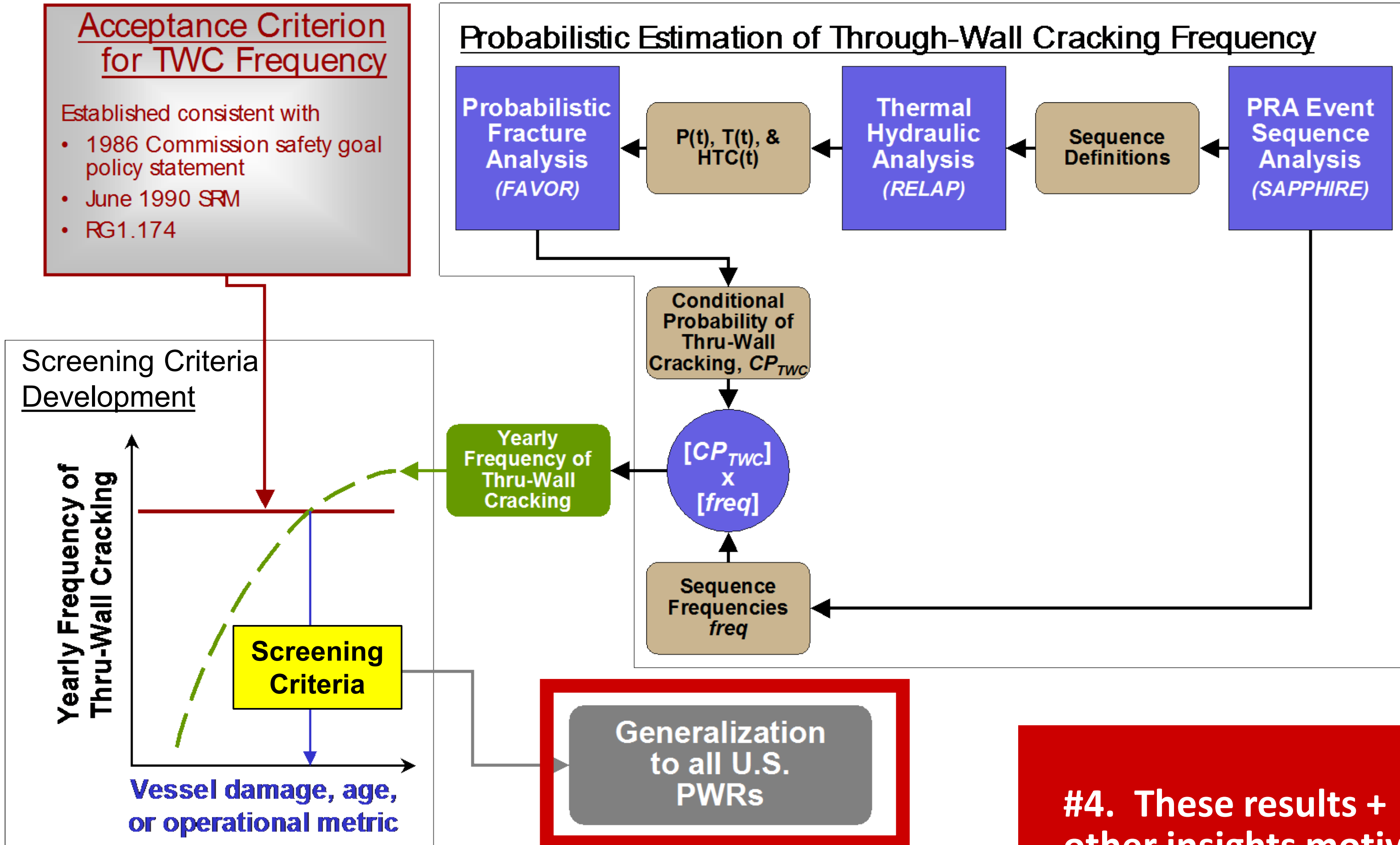
PTS Project – Overall Approach





#3. Metric estimated based on detailed analysis of 3 plants.

PTS Project – Overall Approach



#4. These results + other insights motivate generalization to all plants.

Key Results

- What operational transients most influence PTS risk?
- What material features most influence PTS risk?
- Are these dominant material features / transients common across the fleet?
- New embrittlement screening criteria based on RI calculations

Transient Classes Modeled

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Primary System Faults

- Pipe breaks
  - Large
  - Medium
  - Small
- Stuck open valves that later re-close
- Feed and bleed

Secondary System Faults

- Main steam line break
- Stuck open valves
- Steam generator tube rupture
- Pure overfeed

Important Transient Classes

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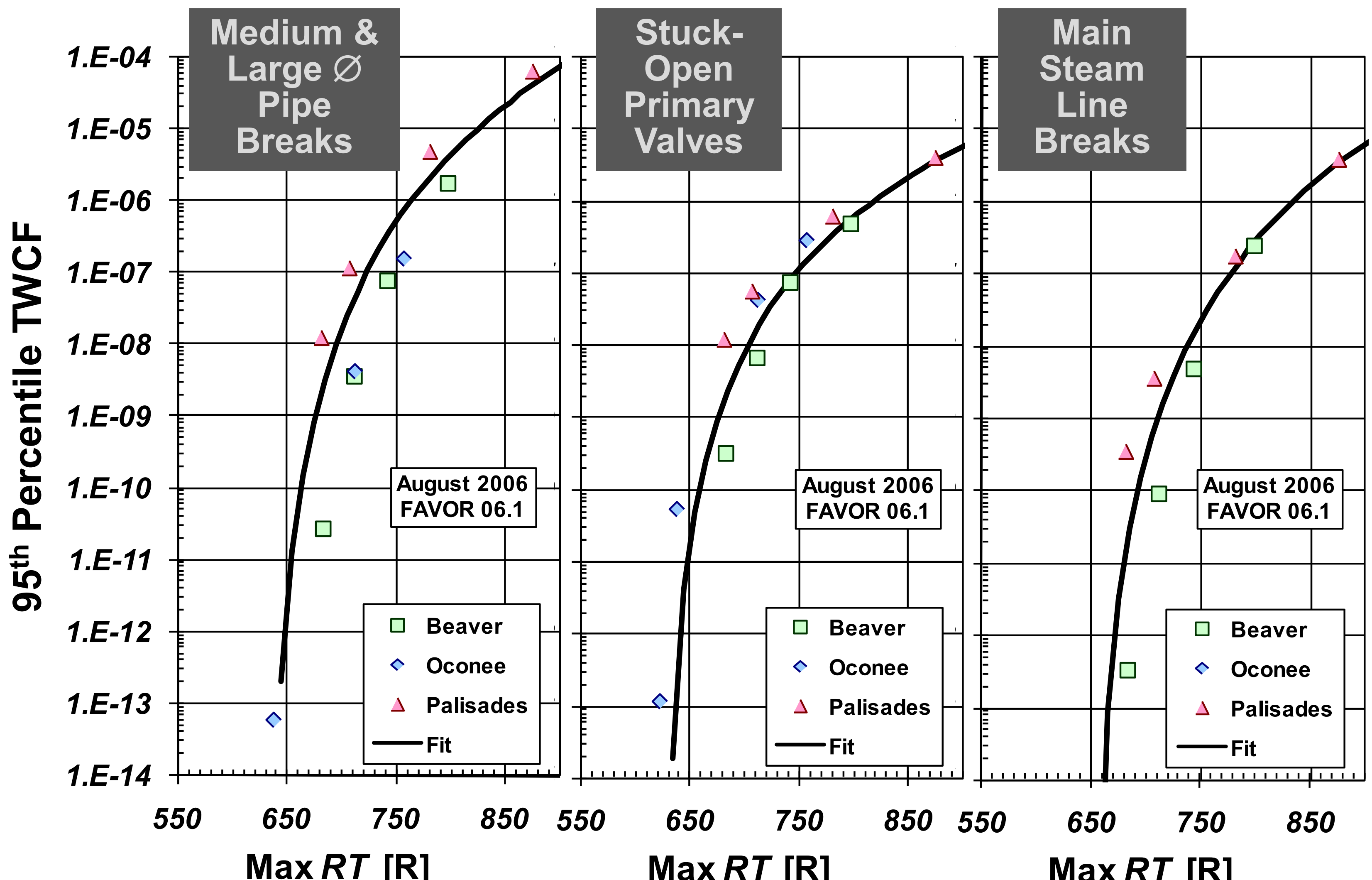
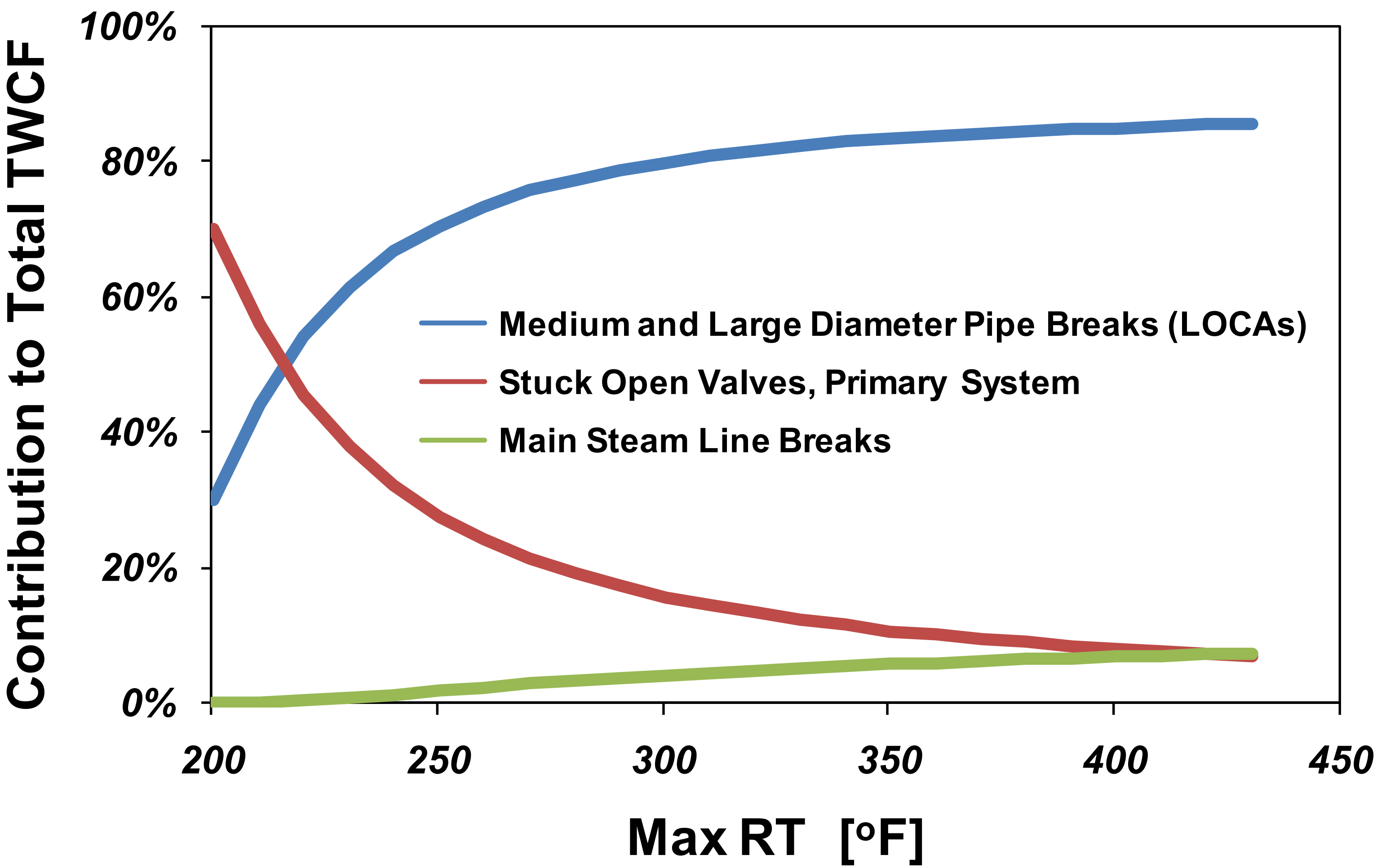


Important Transient Classes



Important Transient Classes

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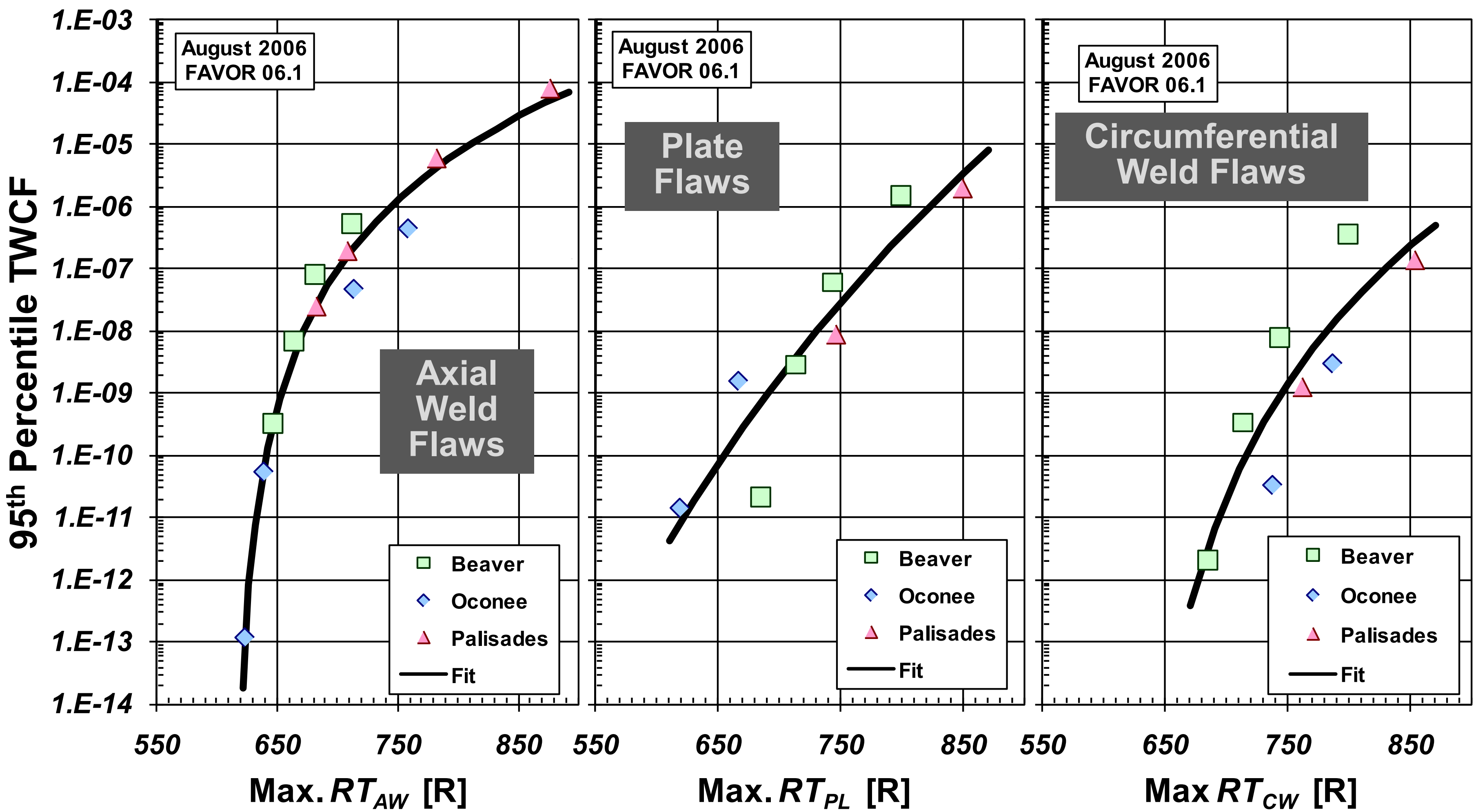
- **Primary side faults dominate risk**
  - Due to low temperature on primary side (35°F)
- **Very severe secondary faults (MSLB) make a minor contribution**
  - Primary side temperature cannot fall below 212 °F, so material still tough even at high embrittlement
- **All other transient classes produce no significant risk**
  - Challenge is low even if transient occurs

Important Material Features



Important Material Features

U.S.NRC
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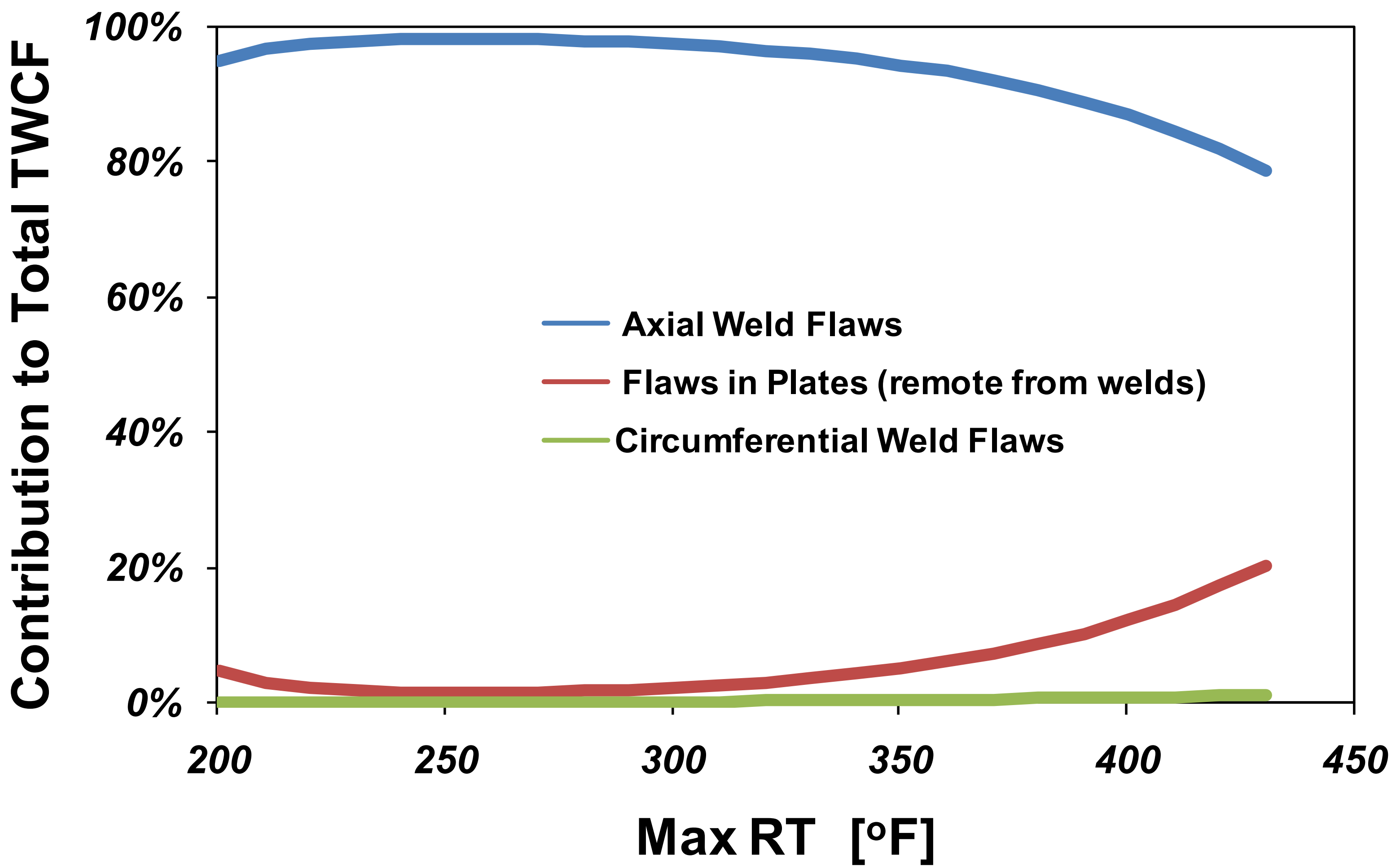

Important Material Features

U.S.NRC
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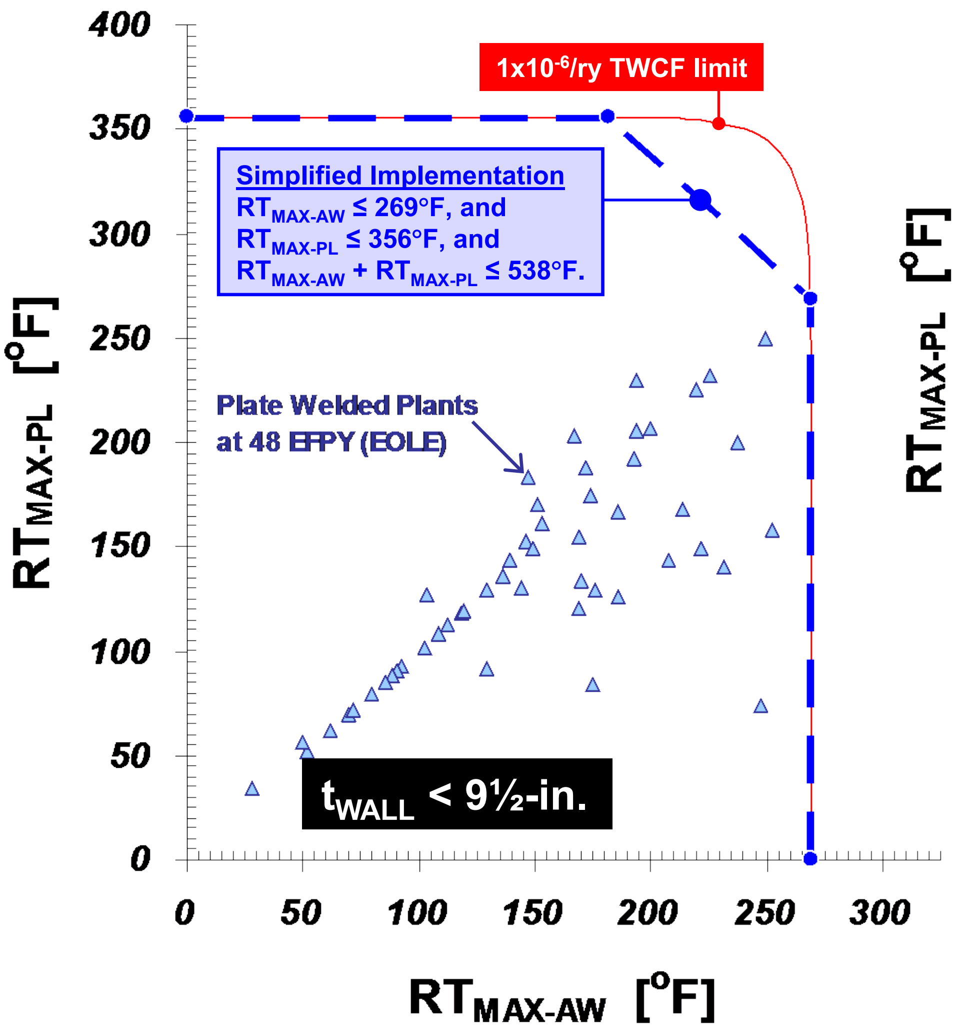
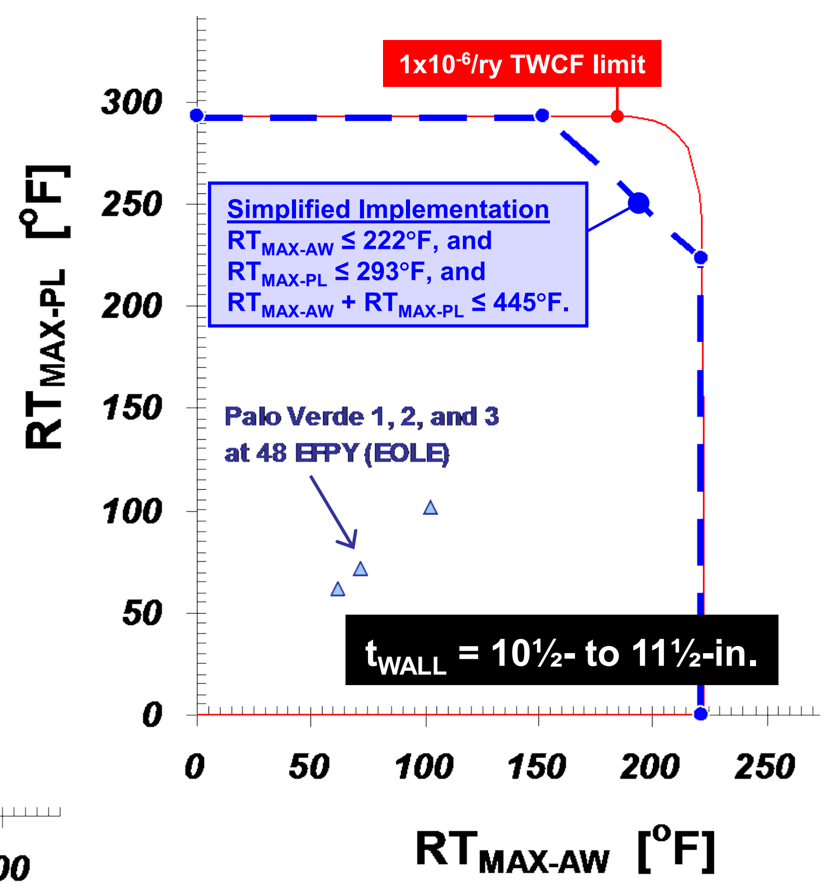
- **Axial cracks dominate risk, circumferential cracks do not**
  - Circ cracks arrest due to vessel geometry
  - Axial cracks are much less likely to arrest

- **Thus, the properties of materials associable with axial flaws dominate**
  - Axial weld properties
  - Plate properties

- **A 3-parameter characterization of RPV embrittlement unifies results across all study plants**
  - Failure probabilities are associated with the responsible material/flaw features

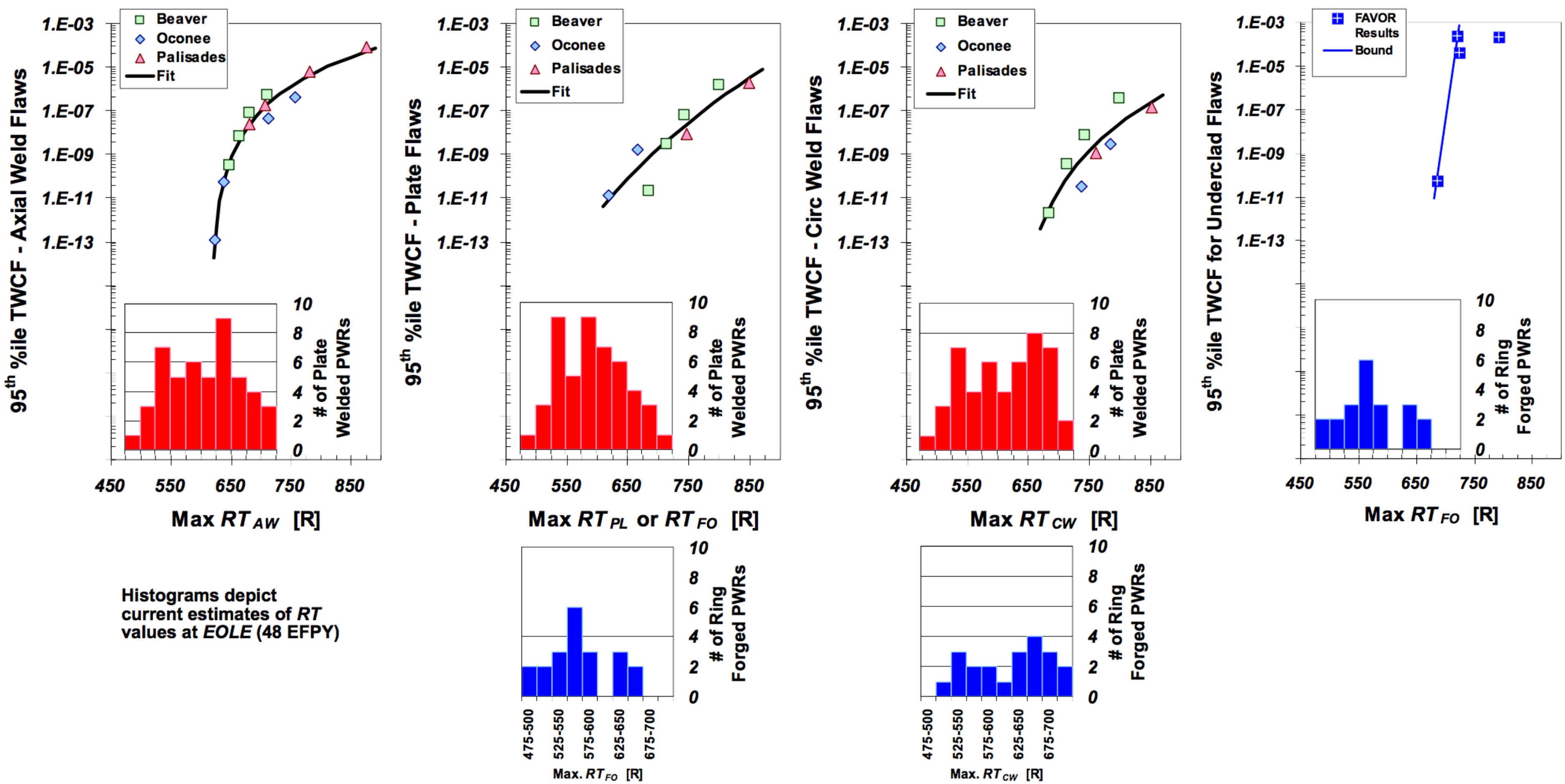
10 CFR 50.61a RT Limits Compared to Plant RT_{NDT} Values





Plant Embrittlement Related to TWCF

Fig 3.12 from NUREG-1874



OVERVIEW OF THE ALTERNATE PTS RULE

(Chapter 2 of NUREG-2163)

Conditions for Use of 10 CFR 50.61a

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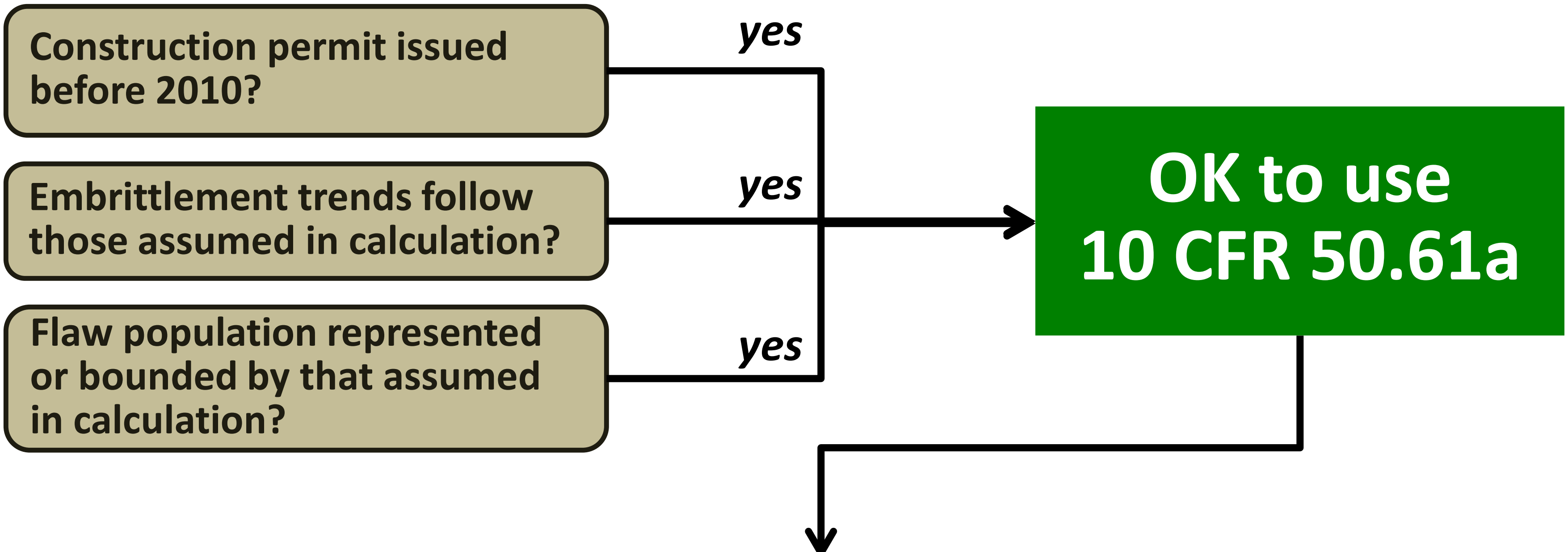

TABLE 1—PTS SCREENING CRITERIA

Product form and RT_{MAX-X} Values	RT_{MAX-X} limits [°F] for different vessel wall thicknesses[6] (T_{WALL})		
	$T_{WALL} \leq 9.5$ in.	9.5 in. < $T_{WALL} \leq 10.5$ in.	10.5 in. < $T_{WALL} \leq 11.5$ in.
Axial Weld RT_{MAX-AW}	269	230	222
Plate RT_{MAX-PL}	356	305	293
Forging without underclad cracks RT_{MAX-FO}[7]	356	305	293
Axial Weld and Plate $RT_{MAX-AW} + RT_{MAX-PL}$	538	476	445
Circumferential Weld RT_{MAX-CW}[8]	312	277	269
Forging with underclad cracks RT_{MAX-FO}[9]	246	241	239

Comparison of 10 CFR 50.61 to 10 CFR 50.61a

Less restrictive reference temperature (embrittlement) screening criteria enable longer operations, but gating criteria must be satisfied to use the alternate rule.

	10 CFR 50.61 *REQUIRED*	10 CFR 50.61a *VOLUNTARY*
Reference Temperature Screening Critera	More restrictive	Better informed, Less restrictive
Plant-specific surveillance data check	Required – 1 test	Required – 3 tests
Plant specific inspection for flaws	Not required	Required

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DG/RG Development Timeline

DG 1.230 = DG 1299

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Date	Event
September 2013	Draft Guide development begins
October 2014	1st ACRS briefing
March 2015	DG & NUREG sent out for public comments
May 2015	Public comments received
February 2015	Staff concurrence (except for OGC final no-legal objection (NLO) finding) on responses to public comments & revisions of RG complete
May 3, 2016	Today's ACRS Briefing
Future	• Incorporate ACRS recommendations into RG & NUREG • Send to OGC for NLO • Publish final RG & NUREG on Federal Register (within ≈ 2 months)

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REGULATORY GUIDANCE

Criteria Relating to the Date of Construction and Design Requirements
(Chapter 4 of NUREG-2163, Position 1 of DG-1299)

Construction Date

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- **Rule & RT screening criteria based on analysis of three currently operating PWRs**
  - **Risk-dominant transients**
  - **Materials of construction**

- **The effect of new reactor designs & new materials of construction on these screening criteria have not been assessed**

- **Therefore the applicability of the Alternate PTS Rule restricted to construction permits issued before February 2010**

- **Licensees may choose to demonstrate applicability to specific reactor designs of their interest**

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REGULATORY GUIDANCE

Criteria Relating to the Evaluation of Plant-Specific Surveillance Data
(Chapter 5 of NUREG-2163, Position 2 of DG-1299)

Plant-Specific Surveillance Checks

Goal

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- Goal: Ensure that surveillance data for the plant being assessed is well, or conservatively, represented by the embrittlement trend equation
  - Used in the probabilistic fracture mechanics (PFM) calculations that provide the basis for the RT_{MAX-X} screening criteria, and
  - That is given by the Rule

Plant-Specific Surveillance Checks

3 Statistical Tests

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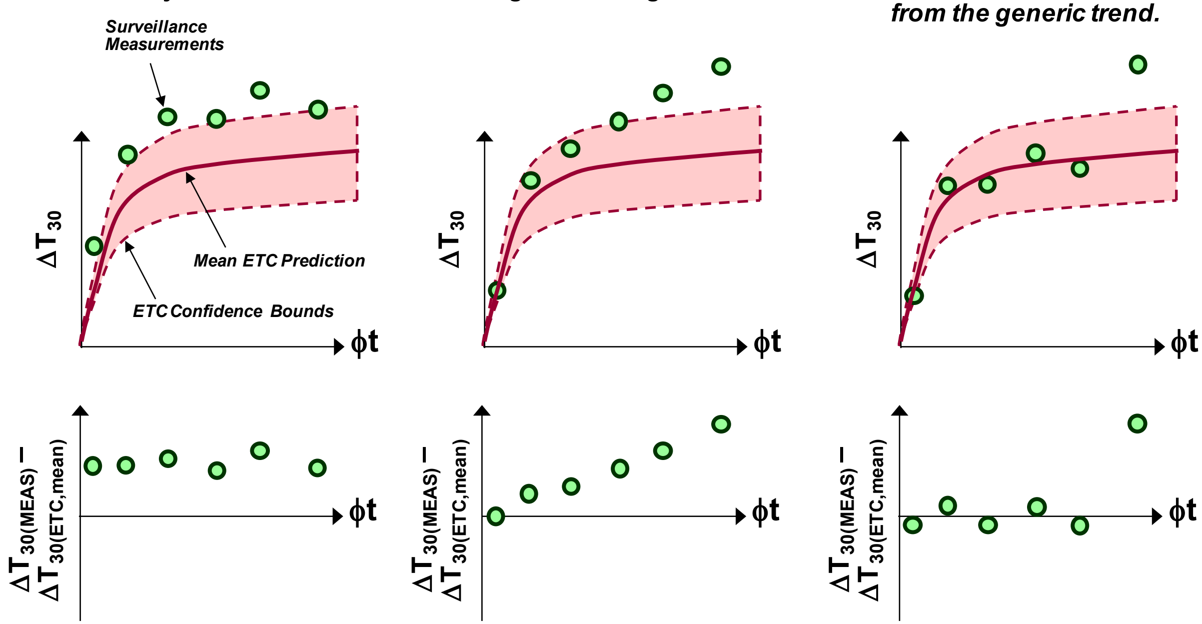
- **Must have 3 or more ΔT_{30} values**
- **Must consider**
  - All beltline plates/welds/forgings for which data is available (not just "limiting" data)
  - Data from "sister plants" if available
- **Only flags under-estimates**
- **3 tests determine different deviations from expected trends**

Mean Test
Determines if measurements are uniformly offset from ETC

Slope Test
Determines if measurements diverge from the generic trend

Outlier Test
Determines of one or two measurements are offset from the generic trend.



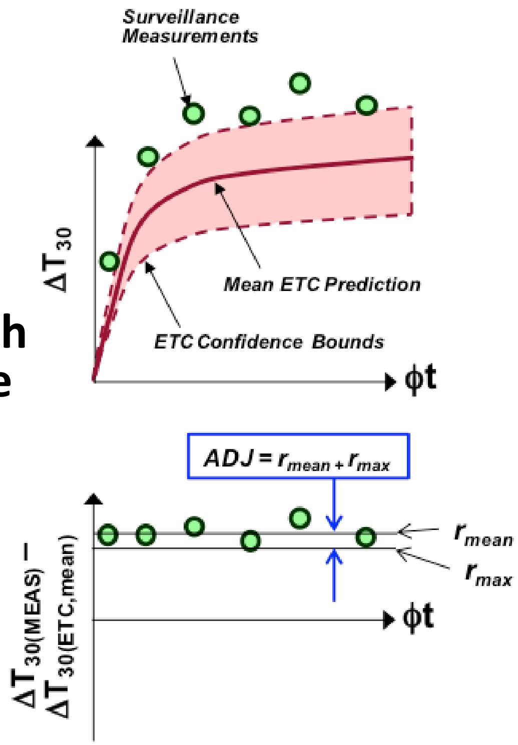
Plant-Specific Surveillance Checks

What if the data fail the test?

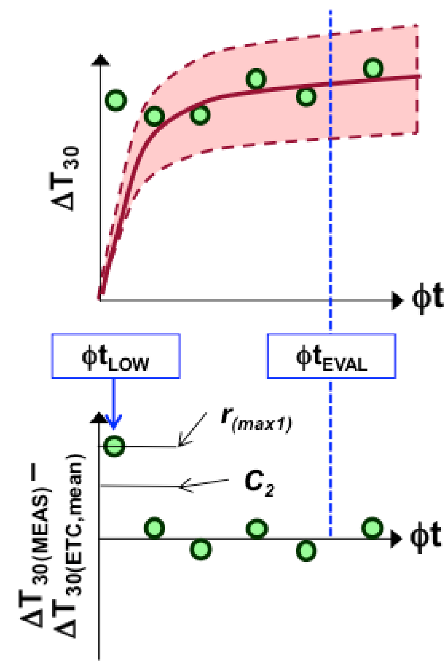
- **Before considering adjustments, consider the accuracy & appropriateness of the input data**
  - **$RT_{NDT(u)}$, # of Charpy values, composition & exposure variables, notch orientation, comparative trends analysis**

- **Adjustment Procedures**
  - **<u>Mean test</u>: Add ADJ**
  - **<u>Slope test</u>: Use greater slope indicated by the surveillance data**
  - **<u>Outlier test</u>: Can ignore a failure at a fluence < 10% of that for the PTS evaluation provided 3 or more data remain**

<u>Mean Test Failure</u>



<u>Low Fluence Outlier Test Failure</u>



REGULATORY GUIDANCE

Inservice Inspection (ISI) Data and Nondestructive Examination (NDE) Requirements

(Chapter 6 of NUREG-2163, Position 3 of DG-1299)

NDE Requirements

Reason for Requirements

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TABLE 2—ALLOWABLE NUMBER OF FLAWS IN WELDS

Through–wall extent, TWE [in.]		Maximum number of flaws per 1000-inches of weld length in the inspection volume that are greater than or equal to TWE_{MIN} and less than TWE_{MAX}
TWE_{MIN}	TWE_{MAX}	
0	0.075	No Limit
0.075	0.475	166.70
0.125	0.475	90.80
0.175		
0.225		
0.275		
0.325		
0.375		
0.425		
0.475		

TABLE 3—ALLOWABLE NUMBER OF FLAWS IN PLATES AND FORGINGS

Through-wall extent, TWE [in.]		Maximum number of flaws per 1000 square-inches of inside surface area in the inspection volume that are greater than or equal to TWE_{MIN} and less than TWE_{MAX}. This flaw density does not include underclad cracks in forgings.
TWE_{MIN}	TWE_{MAX}	
0	0.075	No Limit
0.075	0.375	8.05
0.125	0.375	3.15
0.175	0.375	0.85
0.225	0.375	0.29
0.275	0.375	0.08
0.325	0.375	0.01
0.375	Infinite	0.00

Satisfying the tables ensures that the population of flaws in the vessel is well represented, or bounded, by the population of flaws assumed in the tech-basis calculations.

NDE Requirements

Examination Requirements

REQUIRED	OPTIONAL
Qualified examination in accordance with ASME Code, Section XI, Mandatory Appendix VIII	**NDE uncertainty** (NDE techniques tend to oversize smaller flaws, thereby distributing detected flaws into larger bins where the allowed number of flaws is smaller)
Verification that axial flaws greater than 0.075” TWE at the clad/base metal interface do not open to the RPV inside surface	

NDE Requirements

How Requirements are Invoked

Increasing Risk Significance

Description of Flaws	How are they Assessed
Surface connected on ID, depth greater than 0.075-in. beyond the cladding	Flaw specific assessment of TWCF contribution
Embedded, within 1-inch of inner-diameter	• Assess compliance with flaw tables • If flaw tables are exceeded assess TWCF contribution
Embedded, between 1-inch and 3/8t from ID	• Assess to ASME Code, Section XI, Table IWB-3510-1 • Assess for TWCF contribution if flaw exceeds Table IWB-3510-1
Embedded, beyond 3/8t from ID	No assessment required if flaw acceptance criteria of ASME Code, Section XI, Table IWB-3510-1 is satisfied.

Thermally-driven stresses produce greater risk-significance for flaws closer to the ID. Assessment requirements are more stringent for these flaws.

NDE Requirements

NDE Results Evaluation Process

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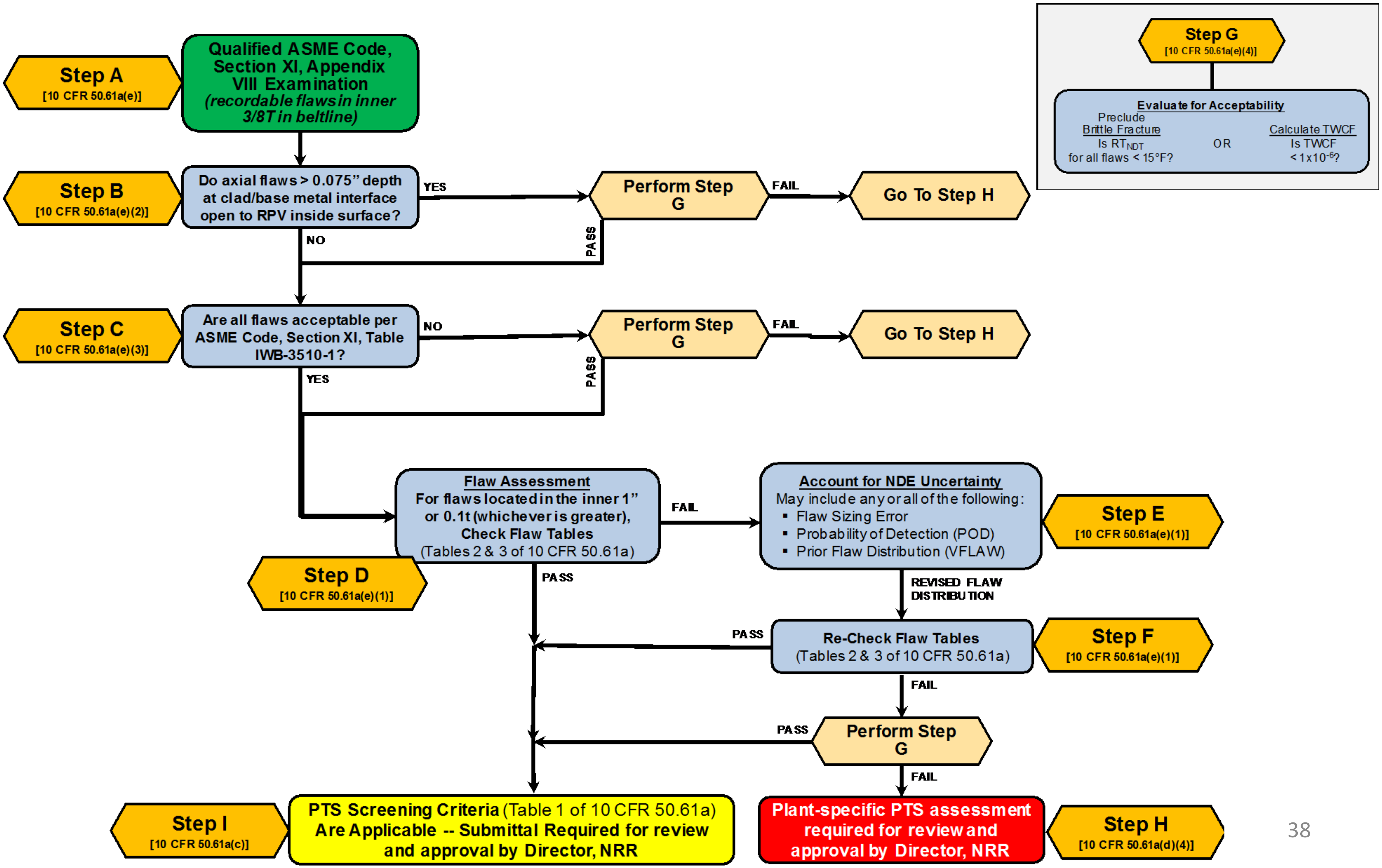

REGULATORY GUIDANCE

Criteria Relating to Alternate Limits on Embrittlement
(Chapter 7 of NUREG-2163, Position 4 of DG-1299)

Alternate Embrittlement Screening Criteria

Why Are They Needed?

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- Paragraph (c)(3) of 10 CFR 50.61a allows for plant-specific analyses to justify operation if projected $RT_{MAX\text{-}X}$ values exceed the PTS screening criteria

- NRC staff elected to develop one method of acceptable guidance for meeting this provision

- Similar feedback was provided by stakeholders

Alternate Screening Criteria on Embrittlement

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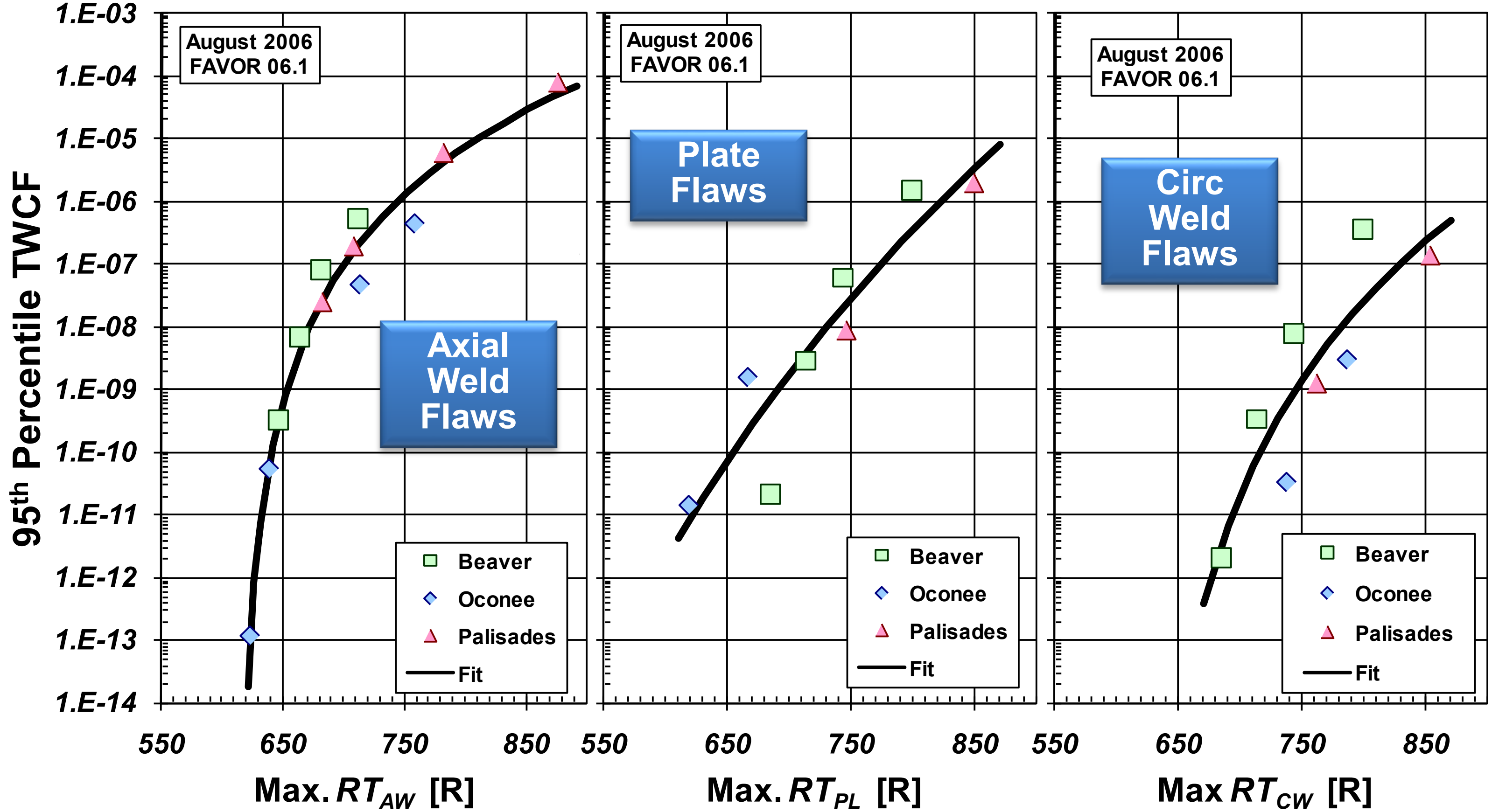

RT screening criteria based on bounding curve fits to PFM results

Alternate Screening Criteria on Embrittlement

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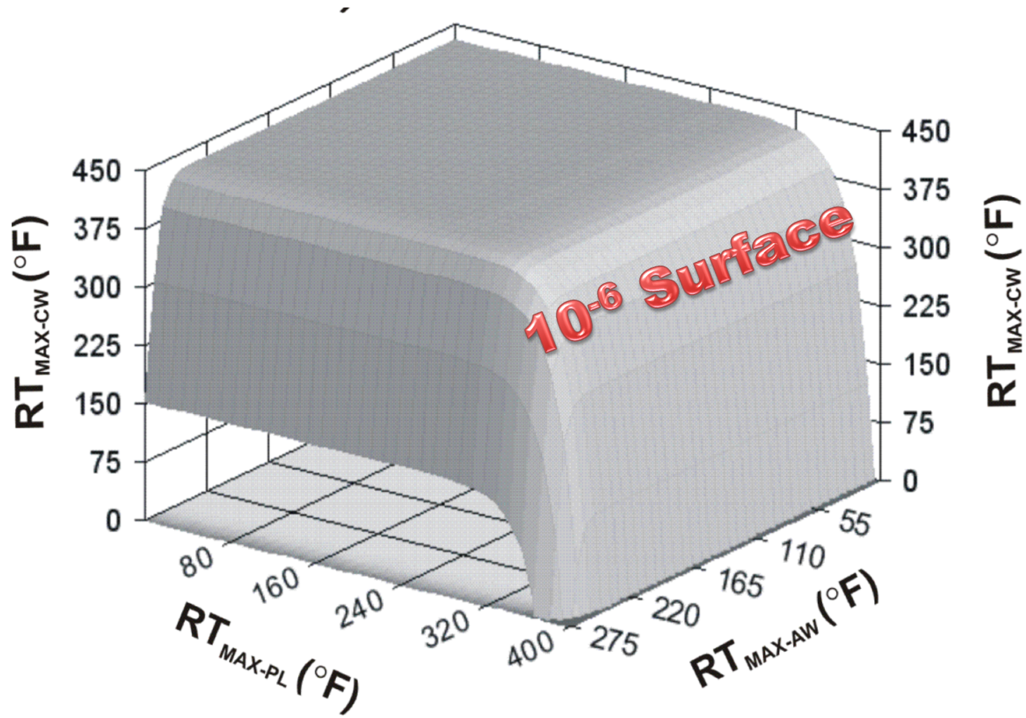
- RT screening criteria table in 10 CFR 50.61a established by inverting this equation
- Simplifications needed to express equation in tabular form
- Licensees can use formula instead of table



$$\text{TWCF Limit} = 10^{-6} > \text{TWCF}_{AWF} + \text{TWCF}_{PF} + \text{TWC}_{CWF} + \text{TWCF}_{FO}$$

Axial Weld Flaws | Plate Flaws | Circ Weld Flaws | Forging Flaws

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Future Use Perspective

Repeat of status from 10/2014 ACRS Brief

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- **Four plants are currently projected to reach 10 CFR 50.61 screening criteria during their 60-year operating periods:**
  - Beaver Valley 1 (2033)
    - Submitted July 2013; under staff review
  - Palisades (2017)
    - Submitted August 2014; under staff review
  - Diablo Canyon (2033)
  - Indian Point 3 (2025)
- **Several plants would likely require 10 CFR 50.61a for 80 years of operation**
- **Other plants may elect to use 10 CFR 50.61a for economic reasons**

Future Use Perspective
Updated Status

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Plant Name	Notes	10 CFR 50.61a use? During LR	10 CFR 50.61a use? During SLR
Beaver Valley Unit 1	• Plate projected to exceed 50.61 screening criteria before the end of LR. • Made 50.61a application in 2013. • Withdrew application in 2015 based on RT_{NDT} recalculation and new surveillance data.	Unlikely	Possible
Diablo Canyon Unit 1	• Axial weld projected to exceed 50.61 screening criteria before end of LR. • Use of 50.61a possible by 2033 (before end of LR)	Possible	Possible
Ft. Calhoun	• Axial weld projected to have RT_{PTS}=268° F at end of LR.	No	Possible
Indian Point Unit 3	• Plate projected to exceed 50.61 screening criteria before end of LR. • Use of 50.61a possible by 2025 (before end of LR)	Possible	Possible
Palisades	• Axial weld projected to exceed 50.61 screening criteria before end of LR. Addressed in 2015 using 10CFR50.61a for LR.	Yes	Possible
Point Beach Unit 2	• Circ weld projected to exceed 50.61 screening criteria before end of LR. Addressed in 2014 using **BAW-2308 approach** through LR.	No	Likely not
Salem Unit 1	• Axial weld projected to have RT_{PTS} = 267° F at end of LR.	No	Possible
TMI Unit 1	• Axial weld projected to have RT_{PTS} = 264° F at end of LR using **BAW-2308 approach**.	No	Likely not

LR = License renewal to 60 years
SLR = Subsequent license renewal to 80 years

Future Use Perspective
Updated Status, Cont.

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- No licensees have indicated short term plans to use 50.61a
- List on previous page may not include all plants considering use of 50.61a
- Plants may elect to use 50.61a for economic reasons – NRC cannot anticipate this use

- Plants have options other than 50.61a to address & manage embrittlement:
  - **Physical options**
    - Fuel management
    - Changing operational characteristics (e.g., heating make-up water)
    - Annealing
  - **Data options**
    - Plant-specific surveillance data
    - BAW 2308
    - Master Curve (PWROG project, CC N-830)
  - **Analytical options**
    - Plant-specific PRA &/or PFM

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CLOSURE & DISCUSSION