Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title: Advisory Committee on Reactor Safeguards (ACRS) Metallurgy & Reactor Fuels

Docket Number: (N/A)

Location: Rockville, Maryland

Date: October 16, 2014

Work Order No.: NRC-1155 Pages 1-168

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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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METALLURGY & REACTOR FUELS SUBCOMMITTEE

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THURSDAY

OCTOBER 16, 2014

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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 1:00 p.m., Ronald G. Ballinger, Chairman, presiding.

COMMITTEE MEMBERS:

RONALD G. BALLINGER, Chairman

SANJOY BANERJEE, Member

DENNIS C. BLEY, Member

CHARLES H. BROWN, JR. Member

DANA A. POWERS, Member

JOY REMPE, Member

PETER RICCARDELLA, Member*

MICHAEL T. RYAN, Member

STEPHEN P. SCHULTZ, Member

GORDON R. SKILLMAN, Member

JOHN W. STETKAR, Member

ACRS CONSULTANT:

WILLIAM SHACK

DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER L. BROWN

ALSO PRESENT:

MICHAEL BENSON, RES

STEVEN DOWNEY, NRO

MICHAEL KEEGAN, Don=t Waste Michigan*

MARK KIRK, RES

EDWIN M. HACKETT, ACRS

BOB HARDIES, NRR

ALLEN HISER, NRR

KEVIN KAMPS, Beyond Nuclear*

NATHAN PALM, EPRI

PAT PURTSCHER, NRR

NEIL RAY, NRR

ERIC REICHELT, NRO

STACEY ROSENBERG, NRR

DAVE RUDLAND, RES

SIMON SHENG, NRR

GARY STEVENS, RES

BRIAN THOMAS, RES

ROB TREGONING, RES

JAY WALLCE, RES

* participating via telephone

A-G-E-N-D-A

P R O C E E D I N G S

CHAIRMAN BALLINGER: The meeting will now come to order. This is - put a muffler on that.

MEMBER POWERS: You're very demanding all of a sudden.

CHAIRMAN BALLINGER: This is a meeting of the Metallurgy and Reactor Fuel Subcommittee. I'm Ron Ballinger, chairman of the subcommittee. ACRS members present are Steve Schultz, Gordon Skillman, Dana Powers, Joy Rempe, and we are fortunate to have Bill Shack here with us as a consultant who's been involved with this process for a long time.

MEMBER POWERS: In other words, he hadn't sorted it out in the past so we're going to let him not sort it out this time.

MR. SHACK: Screwed it up back then.

CHAIRMAN BALLINGER: That's not on the stuff I'm supposed to read. Anyway, and we have Dennis Bley. The staff will brief the committee on draft guide - reg guide 1299 which describes the method that the staff considers acceptable to print use of the alternate fracture toughness requirements for protection against pressurized thermal shock PTS events for pressurized water reactor pressure vessels.

Various guidance relating to PTS will be discussed such as ISI data and NDE requirements. The staff has requested that the ACRS review for release - that's this reg guide - draft reg guide as well as the backup material which is in NUREG 2163 for - to go out for public comment.

The subcommittee will gather information, analyze relevant issues and facts and commit formulated proposed position and action as appropriate for deliberation by the full committee in November, which will be November 6th.

The rules for participating in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on October 8th, 2014.

The transcript of the meeting is being kept and will be made available as stated in the Federal Register notice.

It is requested that speakers first identify themselves and speak with sufficient clarity and volume so that they can be readily heard. Also, silence all iPhones, Droids and other personal devices.

We have not received any request from the public to make oral statements or written comments.

There's a bridge line set up. Pete Riccardella, another committee member, will participate remotely. I don't know if he's here on the line yet.

MR. SHACK: He just emailed. He's in there.

CHAIRMAN BALLINGER: He's in there. That's good news. Okay. But with the bridge line it will be open for comments towards the end of the meeting.

We'll now proceed with the meeting and call upon Brian Thomas to give a brief introduction and introduce the presenters.

I should also say that this issue has been ongoing for seems like decades and there's been a tremendous amount of work that's been done much to the credit of the staff, I think. So -

MR. THOMAS: Thank you, Ron. Dr. Ballinger, thank you very much. My name is Brian Thomas. I'm currently the acting deputy director for the Division of Engineering in the Office of Research.

The folks - before you Gary Stevens and Mark Kirk both are on the staff of DE in the Office of Research. First, express my thanks to the ACRS and the subcommittee for having us here to speak to you on this topic today. Thank you very much for doing so.

As you said, it's - a fair amount has been done in terms of work of the staff on this topic. It's been quite a long time. It's been a very exhaustive undertaking on the part of the staff.

We're happy that we've made the amount of progress that we have made to this point. So we - with that said, we are very happy to be here to speak to you about the implementation guidance - the draft guide 1299 on the PTS rule.

As many of you are aware, the alternate PTS rule was promulgated in 2010. This event culminated a 12-year development cycle which involved extensive inputs by the staff as well as by industry working under the auspices of EPRI and, of course, the public stakeholders.

So that in itself gives you a sense of the breadth and depth and the scope of the reviews that have been undertaken the past 12 years.

The ACRS - I'd also note that the ACRS played a critical role in the development of the 10 CFR 50.61a rule, interacting with the staff on many occasions during the development of the work that's been accomplished.

That said, I'd like to say that the draft guide provides guidance on how licensees can assess their plant-specific data relative to these - relative to the criteria that the staff will speak about in further detail.

Gary Stevens will be briefing on flaws that's addressed in the guide. Mark Kirk will be briefing you on embrittlement criteria that's in the guide.

Additionally, Mark will be providing a brief, and I want to emphasize brief, overview of the background of 10 CFR 50.61a so as to provide the appropriate content discussed. With this introduction, I'd like to turn it over to Gary and Mark. Thank you, Ron.

MR. STEVENS: Thank you, Brian. I'm Gary Stevens. I'll start. Mark, of course, is the expert on PTS and he'll be giving background in the statistical embrittlement data part of it.

I'm a relative newcomer. I've only been involved in this subject for a little over four years and eight months and that's because that's my entire tenure at the agency.

MEMBER POWERS: You should have seen how

he looked before this. You joined when you were 15, right?

MR. STEVENS: Okay. So I just have a couple of slides, a little bit of top level background before Mark gets into the PTS background.

So the NRC issued 50.61a in January 2010 and we have been working on guidance for licensee application of that rule, otherwise known as the alternate PTS rule.

We have two documents which we've sent to the committee that we're looking to go out for public comment on as soon as we can.

The first is a reg guide - a draft guide, DG-1299 - that gives guidance on use of the rule, and the second one is a supporting basis which has been assigned Number 2163.

What we're requesting - well, you requested the brief but we're looking for ACRS review so that we can release both of these documents for public comment.

We often get asked which plants might use the alternate rule and to our knowledge right now four plants are currently projected to reach the 50.61 limits during their first 60 years of operation.

On behalf of my friends in license renewal, I want to qualify that. I'm not - for those fans of Diablo Canyon and Indian Point I'm not making any comment here regarding the staff approval for license renewal of those two units.

I'm just stating that those plants are projected to reach their 50.61 limits in the dates shown here. The staff has two PTS or alternate PTS submittals in-house. Beaver Valley 1 was received in July of last year and that's under staff review, and Palisades was received in August of this year.

MEMBER BLEY: Do you have any projection on when those reviews should be complete?

MR. STEVENS: I don't have any projections on those - completion of those reviews. I don't know if anybody from NRR could offer that input. But I don't. We're allowed three years.

MEMBER SKILLMAN: Gary, in the next to the last bullet it would give you several plants likely to need 61a. Obviously, that's several plants beyond the four that we already identified.

MR. STEVENS: Correct.

MEMBER SKILL MAN: What is the total population that you sense could be requiring use of this for subsequent life renewal?

MR. STEVENS: I personally haven't seen an assessment for that. So -

MR. KIRK: I think it's in the - and I'm going a little from memory here - it's in the eight to ten regime.

But the other thing to point out, which I think the dates here reveal, is Palisades crosses its 50.61 limit of 270F in 2017. So the reason they've come to us is for regulatory reasons.

They don't have legal authority to operate after that without doing something else. Obviously, Beaver Valley doesn't have that as their motivation. My understanding is that they're doing this for economic planning reasons.

They want to make large purchases and investments and so they'd like to know now what the status opinion is on their operability and this is just part of it, of course.

So the numbers we - all we can look at as a regulator is when the particular plants cross particular limits.

But I think as the Beaver Valley 1 submittal reveals, that might not be the total population of people who would see a utility in using this rule in subsequent license renewal and we just don't have the ability to project that.

MEMBER SKILLMAN: But your answer was a number like ten out of a hundred?

MR. KIRK: Yeah. Yeah.

MEMBER SKILLMAN: Okay. Thank you.

MR. KIRK: From a regulatory perspective.

MEMBER SKILLMAN: Thank you.

MR. SHACK: Now, is Beaver Valley 1 projecting some changes in operation to take advantage? Is that included in their submittal?

MR. KIRK: I don't - I have not read their submittal cover to cover. I don't think they talk about that in any event.

MR. STEVENS: Right, but it's been a while and they don't recall. I don't believe so.

MR. KIRK: That wouldn't be something that would normally be put in.

MR. SHACK: Well, you'd have to have increased fluence, for example.

MR. KIRK: Right.

MR. SHACK: And that would be in the submittal presumably.

MR. KIRK: Yes.

MR. SHACK: I hope.

MR. KIRK: Yes.

MR. STEVENS: So I guess we've talked about the last few bullets but the point of those was that, you know, the dates at which plants are expected to hit the 50.61 limits doesn't necessarily reflect the fact they may not use this rule for economic reasons.

CHAIRMAN BALLINGER: I asked this in an email earlier today but I guess that Beaver Valley's the one that's furthest along in the review process. Do we know how far deep they are into the - into the process in terms of what criteria they have met or not met with respect to the alternate rule?

MR. STEVENS: So I'm talking briefly with the NRR staff here. The answer to your question, for Palisades it's too early. Obviously, it just came in. And for Beaver Valley there's been no unexpected issues identified.

They're going through some REIs that focus on the use of sister plant data, which we're going to talk about here as well as some questions on the fluence calculations.

CHAIRMAN BALLINGER: Okay. Thank you.

MR. STEVENS: That's of today. So in terms of what we're going to talk to you about today we're first going to start with background - what is 50.61a and as Brian noted at the beginning that will be brief because we could spend the rest of the week on that alone.

Why was that rule developed, then we'll go into an overview of the contents of the PTS rule - alternate PTS rule.

The stakeholder feedback that we've received and why and how we've received that and then we'll get into what this reg guide talks about and what kind of guidance it gives.

You know, we - there's really - I know there's listed four criteria but predominantly there's two gates that get you into this thing. One has to do with NDE, which I'll be focusing on, and the other has to do with evaluation of plant-specific surveillance data, which Mark will focus on.

One of the other criteria has to do with when you got your data construction and that's really not an issue for the operating plants that we're talking about, and then the last one is an alternate limit for embrittlement and you'll see why we have that.

That's kind of meant to be a first or a next level simplified check, so to speak, if someone doesn't pass the criteria in the alternate PTS rule before they go to extensive plant-specific analysis.

And then, finally, I'll give you, at least as we see it, and know it now what the schedule is for getting this reg guide published. Any questions before we get on with it?

So the only thing I'll note before I turn this over to Mark is on each of these sections I've tried to point you at the specific chapter in the underlying draft NUREG where this material is covered. So you'll see that in each of these slides.

MR. KIRK: Okay. So now it's to me and so those of you that aren't Dr. Powers and Dr. Shack who suffered through probably, I don't know, what part of your life was spent on PTS briefings, now you get the Reader's Digest hyper condensed version unless Dr. Powers asks me a question first.

MEMBER POWERS: I'll reply for the members - this was one of the more enjoyable technical discussions because it was extremely well done.

MR. KIRK: Thank you.

MEMBER POWERS: Largely attributable to

Mr. Kirk.

CHAIRMAN BALLINGER: I might add that he has been invited to various courses and stuff that I've been associated with and he has also acquitted himself adequately.

MR. KIRK: You guys are setting - you guys are setting the bar way too high. So this is the -

MEMBER POWERS: Past performance has no bearing on the future.

MR. SHACK: This looks like a Kirk slide.

MR. KIRK: Okay. My reputation precedes me. So this is - this is the retrospective view on what Mark has been doing for the last 12 years at work and you can see some ACRS liberally sprinkled through here.

But I think the - you know, the things I wanted to point out, as we started to do this in earnest in 1998 but, of course, PTS work had been going on long before that, you know, pretty much continuously since 1985 when 50.61 was promulgated, and I've tried to divide up the activities into sort of major parts and we spent somewhere around four years once we decided to start doing the planning and building the model and updating all our models to migrate them from being sort of the normal regulatory bounding approach to something that was best estimate and considered uncertainties in an integrated and sensible way without double counting. It wasn't until 2001, 2002 that we had an operable code.

Of course, that went through several iterations and I think it was at that point that we started interacting extensively with the ACRS and that's the computing thinking defending phase, when at the end of that we got a nice letter from the ACRS that says we think you did a pretty good job and we will recommend to the commission that you should continue to do a good job.

MEMBER POWERS: Well, we said marginally.

MR. KIRK: That might have been it. It was not a direct quote. It was -

CHAIRMAN BALLINGER: Do you provide same-day service?

MR. KIRK: So then we went into another four years of deciding and approving until finally in 2010 and that, of course, involved public comment, several iterations through NRR, two - actually two releases of public comment of the rule for public comment, and then finally the rule popped out in 2010 and then my graph gave out and so here we are today talking about regulatory guidance for the rule which might be useful to the third person who uses it. So next slide.

MR. STEVENS: Sorry. We are requested for the benefit of Mr. Riccardella on the line to tell him -

MR. KIRK: Oh, sorry.

MR. STEVENS: We're on slide eight.

MR. KIRK: Okay. So on slide eight I just - the next two slides talk about some of the motivations to do the alternate PTS rule work.

From the time that the regular PTS rule 50.61 was adopted in 1985 it was pretty much recognized at that time that there were lots of conservatisms buried in the rule that made the limits more restrictive than they needed to be.

But at the time in the mid-80s that was the best that could be done considering the state of knowledge and the state of computations. Well, things changed a lot in 15 years.

Now we could probably run all these calculations on our cell phones or at least launch a man into orbit. So the technical motivations were to try to do a good integrated study considering all of the uncertainties and what the various-colored arrows indicate is that when we sat down at the beginning of this project and made the list of things that we could do better on in 2000 than in 1985 we found out that yeah, a lot of things, if we did our best effort job in the early 2000s were conservative and so would tend to reduce risk - and those are the green arrows - but there were some things in the original analysis that were either missed or our understanding evolved and so doing a better job on them actually increased risk. So the main point here is we didn't cherry pick. We included all of this in the mix.

So moving on to slide nine, this talks about the regulatory motivations and I think I put too many words on this slide so I'll try to condense it is that in 1985 after Three Mile Island and after so many plants had decided not to be built, nobody was talking about license renewal.

Nobody was talking about subsequent license renewal. Nobody was talking about power upgrades. And so the conservative limits of 50.61 seemed just fine. They weren't too limiting.

By the time we fast forward to the early

2000s and we're looking at at least power upgrades and license renewal, then the staff starts to see okay, if we keep these limits we're going to be dealing with on the order of half a dozen to a dozen plant-specific assessments, plant-specific submittals all doing the exact same thing.

So we could either do that or, before all that bow wave starts to hit, we could do a good integrated assessment of the whole thing, be able to engage industry in an appropriate way to get the plant-specific data that we needed and to engage the experts that we needed to do something more generically and that's the approach we took.

So moving on to slide ten, this is probably something that Dr. Shack will say is another marker slide so this is my - not my simplest flow chart - I've got one that's simpler coming later - attempt to explain the overall project approach in one slide.

So we start off with commission guidances in the 1986 commission safety goal policy statement, 1990 staff requirements memorandum and reg guide 1.174 that allows us to establish a risk-informed performance metric.

So that sets our limit and we had many

discussions on that, and I prefer to avoid the Dr. Powers questions that I couldn't answer then and I can't answer now.

We came up with a value of ten to the minus six on through-wall cracking frequency, so that was one part of it. The next part was how to make a credible calculation of through-wall cracking frequency and how that changes with, let's just say, generically vessel age to compare.

So then the second step is to model the plant, model the reactor pressure vessel in this case, to estimate the performance metric.

So here we start, and I should have a start block in the upper left hand - upper right hand corner with a PRA sequence analysis which defines both the sequence of things that can go unfortunately wrong and the frequency with which they go unfortunately wrong.

Remember the frequency per minute save the sequence definition, those get fed into a thermal hydraulic analysis.

We use relap. That defines the temporal variation of pressure, temperature and heat transfer coefficient on the inner diameter of the reactor vessel and the down comer region.

That feeds into the probabilistic fracture mechanics analysis using favor, which has a lot of other inputs that are cleverly hidden in this slide like fluence, copper, flaws and so on.

Out of that we can calculate a conditional probability. Through-wall cracking is conditioned on that sequence of unfortunate events actually having occurred.

We then do a matrix multiply of the frequencies of those events and we get a yearly frequency of through-wall cracking integrated with the plant.

We do those analyses at several different levels of embrittlement and we get a curve like I've sketched here and I'll show you actual calculated data in a little bit.

MEMBER BANERJEE: Mark, just remind me the relap analysis does that take into account the possible fingering effects on the down comer?

MR. KIRK: No.

MEMBER BANERJEE: So it's just a gross -

MR. KIRK: Yes. It's a one dimensional analysis.

MEMBER BANERJEE: And that then is somehow related to three dimensional effects? I don't remember -

MR. KIRK: No, we went through lots of discussion on that.

MEMBER BANERJEE: It was before my time.

MR. KIRK: Yes. There are - I've heard them called fingering, plume, thermal streaming effects but you also get - if the region of the - I'll try to do the condensed version - if the region of the vessel that we were concerned about were right under where the streaming is coming in, if you were doing a nozzle analysis, you know, that's the whole game. You have to account for it.

MEMBER BANERJEE: It's high up. Is that it?

MR. KIRK: Yeah. But there - once you get down to the down comer there is sufficient mixing that it diminishes the strength of the plume. I'm trying to remember the numbers. It was something like -

MEMBER BANERJEE: But Graham Wallace blessed this.

MR. KIRK: He accepted it. I don't think he was thoroughly -

MEMBER BANERJEE: I wouldn't second guess it.

MR. KIRK: Yes. We might have worn him down.

MEMBER SKILLMAN: Mark, you communicated that you used several levels of embrittlement. From where do you get those levels of embrittlement?

MR. KIRK: So they are based on - so in each vessel we have the different materials in the vessel, the different plates, welds and forges. They each have chemical compositions and unirradiated properties and then, of course, fluence.

All of that goes into the embrittlement trend calculation like in reg guide 199 and what we do is we just do calculations, say, with 40-year fluence, 50-year fluence, 60-year fluence to get the different development options.

MEMBER SKILLMAN: Okay. Thank you.

MR. SHACK: Mark, do you recall just roughly how many sequences you did for the thermal hydraulics?

MR. KIRK: It was in the neighborhood of 60 to 70. So the entire population of all the things that could possibly go wrong get binned up by the PRA analysis into 60 to 70 different things.

So then based on - we used that process to do a very detailed analysis of three pilot plants - Palisades, Beaver Valley and Oconee - and then we interrogated those analyses to try to understand what were the most risk-dominant sequences and what were the most risk-dominant material features, and that led us to being enabled to take these results and then generalize them for use in all U.S. PWRs and that's the embrittlement limit tables that you see in the current 50.61a rule.

I'm sorry. This is slide number 13 and now we're going to slide number 14. So now I'd like to go through - so that's how we did the calculations and then there was a lot of work and then we finally got down to the summary of key results.

So I'd like to talk about basically the transience and operational features and the material features that most influence PTS risk.

So in the transient classes and, as the committee knows, this is not my area, I'm going to say we modeled pretty much anything that anybody could dream up, including certain current members of the panel, as to what could possibly go wrong and lead to an overcooling sequence, and we tried not to a priori screen anything out unless I think there was a number, like, ten to the minus eight in event frequency where things just didn't get included.

But pretty much what I can tell you from the calculations is we included a lot of sequences where we just wound up calculating a lot of zeros in terms of through-wall cracking frequency.

For example, a steam generator two rupture - it's a tiny hole in the system. Bad for the steam generator, of course, but in terms of the vessel it just doesn't matter.

So we model all these transient classes but then in the end if we can sort of bin things up into three major types of sequences that can lead us to reasonably significant values of through-wall cracking frequency on the - working from left to right on your slide - medium and large diameter pipe breaks, stuck open primary system valves in the middle of main steam line breaks.

One of the questions that frequently gets asked so I'll ask it rhetorically now is in the original PTS analysis in the 1980s main steam line breaks were seen to be a major risk contributor.

However, now if you do a visual comparison of these curves you see it the same embrittlement level, and I'll pick 750 degrees Rankine, which is 290 degrees Fahrenheit, you see that the main steam line break is coming in at about two times ten to the minus eight whereas a medium to large diameter pipe break is an order of magnitude and a half or two orders of magnitude higher at, like, six times ten to the minus seven. So why the change?

Well, the change is not anything inherent to the main steam line break but just how it was modeled in the initial analysis. In the initial analysis, of course, main steam line is a huge pipe rupture.

So the initial cool down is screening fast but in the initial analysis it was modeled conservatively as going down to a minimum temperature of the ambient temperature of water whereas in our analysis we simply modeled it as going down to the boiling point of water, which is more appropriate because it's a secondary side break, not a primary.

So the primary is not going to go down below boiling and that makes a huge difference in terms of the calculated failure probabilities. So basically what the -

MEMBER BANERJEE: This is the temperature where?

MR. KIRK: This is the - no. This is not the temperature where. This is the reference RTNDT - the reference temperature of the materials.

MEMBER BANERJEE: Embrittlement.

MR. KIRK: Yes, so as embrittlement is increasing your through-wall cracking frequency associated with the flaws in the vessel is going up and that's what these - that's what these graphs are showing. Maybe an easier way to make -

MEMBER BANERJEE: The thermal hydraulics is embedded in that?

MR. KIRK: The thermal - yeah, the thermal hydraulics. Each data point here represents the stated plant - the integrated through-wall cracking frequency results for all the thermal hydraulic transience in that category at that plant, and the big revelation finding, I'd say, out of this is that only the big breaks matter.

Once you get down to the smaller breaks either, you know, you're calculating on the ten to the minus 13th number so who really cares, or they're zero. And this is - it's on this slide that the explanation of, well, how can you have a one-size-fits-all embrittlement when you have CE plants and Westinghouse plants and B&W plants.

It's that they're all basically the same, more or less, the same diameter. The steam lines are the same diameter.

The primary site piping is the same diameter. So the - for the bigger events the thermal hydraulic response is very similar and in any event the vessel can only cool so fast. Most of the -

MEMBER BANERJEE: Why is there just one pink triangle on the large grade or medium grade?

CHAIRMAN BALLINGER: There's not. No, there's four. There's four. I think -

MEMBER BANERJEE: Yes, but I mean what is special about Palisades? That's what I was going to ask.

MR. KIRK: Well, there are so many things that are special about Palisades. Why is there -

MEMBER BANERJEE: Why is that big pink - the triangles have such a higher - yeah.

MR. KIRK: Oh. Because it's at a high embrittlement level. So the -

MEMBER BANERJEE: That's due to just

Palisades being there?

MR. KIRK: Well, what you see is we modeled - this is Palisades at - the first point on each graph is the plant at 32 EFDY or 40 years of operation. The second is at 16 and these are rather ridiculous amounts of operating time if we just turned up the fluence crank to get embrittlement levels above our - above our risk method. So where Palisades is operating today in South Haven, Michigan is down here.

They're not up here, and so yeah, the plant names here reflect that we did plants -

MEMBER BANERJEE: There's nothing special about Palisades, though, than you exposed it to a lot of risk?

MR. KIRK: A higher level of embrittlement, yes. And the point of this graph is showing that even though, you know, we have a CE plant, we have a Westinghouse plant, we have a B&W plant - they have different designs, they have different operators, they have different training - within these broad categories of challenge events the trends are very, very similar.

CHAIRMAN BALLINGER: Where is Palisades in 80 years if you can convert that to fluence?

MR. KIRK: Well, it's probably over hereish.

CHAIRMAN BALLINGER: Okay.

MR. KIRK: Right. I know that doesn't go well into the transcript but that's probably about the accuracy.

CHAIRMAN BALLINGER: But it's less than one times ten to the minus six, let us hope.

MR. KIRK: Yeah.

MEMBER BLEY: Mark, for those of us who aren't structural mechanics folks and had spent years drawing pictures of the stress profile and the vessel wall with the pressures and temperatures added up, the big surprise was that there's no P in PTS. I mean, it really -

MR. KIRK: Well, actually -

MEMBER BLEY: - the key - actually it's a low pressure scenarios -

MR. KIRK: Yeah.

MEMBER BLEY: - with the high Delta T's that are killing us.

MR. KIRK: Yeah.

MEMBER BLEY: Well, not killing us - that are -

MR. KIRK: Well, they're - and that's one of the - in fact, that was very much a surprise because in the - in the early analysis - in the 1980s analysis the no-pressure events were a priori screened out.

But what we found in running the calculation is you can run a crack pretty much all the way through the wall.

MEMBER SKILLMAN: Just with temperature.

MR. KIRK: Just with temperature.

MEMBER SKILLMAN: Just with temperature.

MR. KIRK: Yes.

MEMBER BANERJEE: So this is happening during the reflux phase for the large grade?

MR. KIRK: It's happening - all of these events happen very early on in the transient before the operator could take any action.

MEMBER BLEY: So when the cold water hits and -

MR. SHACK: We have a comment from Dr. Riccardella - why do you present this plot in terms of degrees Rankine. And then there's another one. Sounds like Sanjoy could use a primer on fracture toughness transitions.

MEMBER BANERJEE: What does that mean?

MEMBER REMPE: That should truncate some of his comments.

CHAIRMAN BALLINGER: Is this on - is this on the record?

MEMBER BANERJEE: What does this got to do with fracture toughness?

MR. SHACK: That's the RT.

MEMBER BANERJEE: Oh. That's the -

MR. KIRK: So yeah, this is - I should have said at the beginning these graphs show as embrittlement increases, as transition temperature increases, so does the through-wall cracking frequency and leading to more pipe breaks, stuck open valves and the largest through-wall cracking consumption and main steam line breaks are a smaller contributor.

Go to the next slide quickly. There we go. Slide 17, now we're back in degrees Fahrenheit. I used Rankine because he's a Scottish engineer and I'm Scottish and also I couldn't put an exponential through zero.

So this graph is the same as the previous slide, same curves, except now I've gotten rid of the data points to make my life easier and we were just now comparing the percent contribution to the total through-wall cracking frequency as embrittlement evolves.

And so now that's it in Fahrenheit it's easier to see our current PTS limits are in the 270 to 300 regime so we're seeing there that medium and large diameter breaks are the most important thing than stuck open valves, than main steam line breaks.

But the other thing that you see is that the risk importance of the these various transient classes changes as embrittlement changes.

Now, you're probably not too worried about the contribution to the total through-wall cracking frequency at 200 degrees Fahrenheit because the through-wall cracking frequency is, like, one times ten to the minus 12.

But if you were you would realize that you need the stuck - it's the stuck open valves that are dominating because they are - you do need compression. But once you embrittle sufficiently you can get just thermal events control.

Anyway, next slide. And I think we've said all this. So the big take-aways here are that primary side faults dominate risk. Why is that?

Because they can go to very low

temperatures relative to RTNDT as a part of the transient. The secondary side faults make a very minor contribution simply because of the higher end temperature and - I think I mentioned this - it's the big - it's the big breaks that are the most similar between the different plants that are the ones that are dominating risk and that helps us - helped us to develop sort of one-size-fits-all screen criteria.

MEMBER SKILLMAN: Mark, where would you get 35 Fahrenheit on primary? Where would that come from?

MR. KIRK: Injection from an external storage tank that's not temperature controlled and I think that was something that the conservatism played, frankly, during the winter.

MEMBER SKILLMAN: Aren't most PWSTs or RWSTs maintained at or above 70 or 75 degrees Fahrenheit?

MR. KIRK: You're more the expert than me so I'm just going to say yes. I think -

MEMBER SKILLMAN: If it weren't this would be a -

MR. KIRK: No. Yeah. No? Gary?

MR. STEVENS: My experience I've seen them

- yeah, much - going much lower. I don't know about 35 but certainly 50.

MEMBER SKILLMAN: I've seen them at 50. That is certainly conservative.

MR. KIRK: Yeah. And so you - and actually that's a good point. I mean, if 50 is the right number and, you know, years have passed since this - and this wasn't my personal part of the analysis anyway - even in a so-called best estimate uncertainty blah, blah, blah analysis conservatisms like that creep in. They're still in here.

MEMBER SKILLMAN: Okay. Thank you.

MR. KIRK: Okay. So next slide. Now we'll go to material features. Here, again, embrittlement plotted versus through-wall cracking frequency but now we're going to look at the contributions to through-wall cracking frequency of different flaw populations. So the most dominant is axial weld flaws.

In the middle we have plate flaws and over here we have circumferential weld flaws and, again, I'd call your attention to the differences between these at a referenced temperature axial weld of 290 degrees Fahrenheit or 750 Rankine.

Axial weld flaws are contributing ten to the minus six. Plate flaws are contributing two times ten to the minutes eight so an order of magnitude and a half lower.

Circ flaws are down at one times ten to the minus nine so another order of magnitude less, and the reason for these differences all have to do with the orientation and size of the flaws that were thought to be representative based on destructive analysis of RPV's and were therefore simulated in the DFM code.

Axial weld flaws are the biggest and, as you might guess by the name, they were oriented axially so due to the geometry of the vessel and the stress loading, axial flaws tend to go through once they initiate whereas circ weld flaws it's the same flaw population, same size, same number - well, actually probably more because the circ weld is longer.

But they're oriented circumferentially so even though they're as likely to initiate as axial weld flaws, as you go through the vessel the crack driving force starts to drop off after you go about 30 percent of the way through the vessel and they naturally arrest.

MEMBER BLEY: Now, the old studies back when Robinson, I think, was the poster child didn't have crack arrest in the models, if I recall right. I believe circumferential welds I think were the leading contributor.

MR. KIRK: Right. And if - and in other - well, no other country does these calculations this way in terms of using a probabilistic approach.

Other countries that are considering it or doing research studies like France and Japan tend to focus on a crack initiation criteria, not a through-wall cracking criteria, and so they have, as you correctly pointed out, an equivalent contribution of circ welds to axial welds.

You know, here's one of the big take-aways. Right now in PT limits and PTS under 50.61 we talk about plants that are circ weld limited. Just look at the - there are no more plant - in 50.61a if somebody uses that there are no plants that are circ weld limited simply because the risk significance is so small and plate tends to be in between because, A, the flaws are smaller, and B, they're not all oriented circumferentially.

MEMBER BLEY: Is that - what happened to Robinson? Did it get better?

MR. KIRK: H.B. Robinson?

MEMBER BLEY: Yeah. They used to be the one that - I mean, the original studies were done on Robinson, as I recall.

MR. KIRK: Yeah.

MEMBER BLEY: Because people thought it was the most vulnerable at the time. They're no longer in that -

MR. KIRK: I -

MEMBER BLEY: - in the list of lead plants.

MR. KIRK: I can't answer your question. I haven't - it hasn't been on the list for so long I don't know.

MEMBER BLEY: Okay.

CHAIRMAN BALLINGER: Can I just confirm something in my mind? The through-wall cracking frequency annual per year, that number -

MR. KIRK: Is per year.

CHAIRMAN BALLINGER: That accounts for the probability of an event occurring - the steam line break occurring. It doesn't assume that one occurs?

MR. KIRK: Yes.

CHAIRMAN BALLINGER: Okay. All right.

MR. KIRK: Yes, it does. These are all event-weighted frequencies.

CHAIRMAN BALLINGER: Okay.

MR. KIRK: Okay. And the next slide, slide 20, is again, just the same as the previous slide but with the contributions expressed as a percentage.

And so the clear message here is that it's the axial weld - it's the axial weld flaws that are driving the risk and therefore in the embrittlement limits in the alternate PTS rule it's the materials that can be associated with the axial weld and their embrittlement characteristics that are the most limiting.

So that means the plates in the axial weld because they're both butting up against the fusion line are the things that are important and the circ welds - I mean, they still get checked as they should but any plant that was circ weld limited before like Kewaunee, which shut down, from this perspective has no problems. So next slide. So we've talked about -

MEMBER BLEY: Well, your last statement I think was important that they still need to be checked -

MR. KIRK: Yes.

MEMBER BLEY: - because all of this assumes some flaw distribution -

MR. KIRK: Right.

MEMBER BLEY: - might not be there if you're not -

MR. KIRK: That's correct. Yeah. I'm not saying we don't check the circ welds or don't require that the plants check the flaw distribution.

That's - you know, we're going to be discussing that. All I'm saying is if I'm operating a plant and I have what's been identified as a circ weld limited plant, if I'm bumping up against the original PTS limit there's a huge incentive to go to this because it's risk informed.

So let's see, we'll go to slide number 22. What this slide does, and I think we have a depiction of the table of reference temperature limits later, but this provides a graphical representation of the reference temperature limits in 50.61a versus an assessment of where all - where the plate plants sit at 4080 FPY.

So I've taken the circ weld reference temperatures off this because they really don't contribute.

But what the - what the tables give you is pretty much a zone of maximum reference temperature in the axial weld, the maximum reference temperature in the plate within which you're acceptable by the rule and that's depicted by the blue square with the top chopped off, and then all of the dots are our assessment based on the data in the - our database of the plate plants after operation to 4080 FPY.

As you can see, everybody's inside the limit at 4080 FPY and the two graphs just help to indicate that one of the features in the rule is that these limits are also a function of the thickness of the vessel wall simply because thicker walls can have higher thermal stresses and so they need more restrictive limits.

But there's really only one thick wall trio TWRs out there. They're Palo Verde and unless our - the generic information that we did to make this graph is wrong, they don't have any issues and so they're not likely to use this rule.

Okay. Were there any more questions on that section? Okay.

MR. STEVENS: Well, you were right. I'm impressed. For the first time in my relatively short tenure here I've never experienced a summary discussion of PTS that only lasted 40 minutes. So that was good.

MR. KIRK: So we're only 10 minutes over.

MR. STEVENS: Okay. So I'm going to - this is meant to give you a very brief and very high-level overview of the alternate PTS rule.

As we get into the detailed discussions on the guidance we'll go into - it's much more complicated than what these slides would suggest. But we're trying to walk into this a little slow here.

Basically, there are three top-level conditions that allow use of 50.61a. The first one has to do with the construction permit being issued prior to 2010 and for the operating that's not an issue.

And then the second two are the ones we're going to be talking a lot of what we call gating criteria for use, the first one having to do with the embrittlement transit plan - are they following those that were assumed in all of the background calculations, and the flaw population that a plant might find through their plant-specific ISI and whether that population is well represented or bounded by the flaw population that it's assumed on the basis for the rule.

If all three of those conditions are met, yes, then you're allowed to use the rule and here is the tabular form of those graphs that Mark just showed you.

MEMBER BANERJEE: So is the - are the results very extensive with small population - what you are doing?

MR. KIRK: Oh, absolutely.

MR. STEVENS: Yes. And so - well, go ahead. Yes.

MEMBER BANERJEE: Otherwise, if there are no flaws you could have a lot of - have a gating criteria.

CHAIRMAN BALLINGER: I see this - I see the number 269 up there. Is the nine significant? What is the -

MR. KIRK: You mean versus 270?

CHAIRMAN BALLINGER: Or 271 or 265 or - I mean, what - how good at -

MR. KIRK: Well, what we - the numbers in this - we need to go back a few slides, back, back, back - forward. We're on slide 19. So the numbers in that table - this is basically the set of graphs that you use to get the numbers in the table so you -

CHAIRMAN BALLINGER: So just the fit numbers?

MR. KIRK: It's the fit. So you say the total through-wall cracking frequency is ten to the minus six. It's equal to the sum of these three parts and then you reverse the equation and we just took it to the - a whole number. You can't set regulatory limits with an ish on them. It doesn't work too well.

MEMBER STETKAR: I was going to say it's 300. I was almost going to say 300-ish would have been okay with me.

CHAIRMAN BALLINGER: Well, but a licensee is going to do a calculation through this thing and they're going to come up with a number.

MEMBER POWERS: Well, I should remind the members Kirk's promise when he started off on this work, which was to do a completely rigorous and certain analysis.

MR. KIRK: I was much younger then.

MEMBER BLEY: On the other hand -

MEMBER POWERS: And it is possible -

MEMBER BLEY: - I don't know a more complete one.

MEMBER POWERS: Yeah. Reverse that

calculation and come up with uncertainty bands on these things if one did a completely rigorous uncertainty analysis.

CHAIRMAN BALLINGER: We have commented before that this is the best analysis that we've seen.

MR. STEVENS: Okay. So we do have a slide on the first box. We're back on slide 24, by the way. The first box regarding construction we have one slide but we're going to spend the bulk of the time discussing the guidance associated with the other two boxes here and how those conditions can be satisfied, or not.

In comparison this table's kind of nice. At least I find it very useful to compare 50.61 to 50.61a. You know, 50.61a is a voluntary alternative to 50.61 and in essence it does provide better informed less restrictive limits but there's a price for that and the price is in plant-specific surveillance data checks there's more required - three in the case of 50.61a versus one for 50.61 - and then plant-specific inspections for flaws that's not specifically required in 50.61 but it is required to apply 50.61a.

MEMBER SKILLMAN: How much work - how much work is required for those last two entries on the lower right hand corner? What is the real difference between requiring one test, requiring three tests and not required versus required?

CHAIRMAN BALLINGER: The third one's probably - the third one's the killer.

MR. STEVENS: I'm not sure how to answer that in terms of how much effort's involved.

MR. KIRK: Well, for the plant-specific surveillance data check that means you need two more columns in your spreadsheet. So it's - this is not an official position of the NRC.

It's just Mark's opinion. I don't think it's an undue regulatory burden. But the third one is significant. We require a plant-specific ISI.

Now, this is what, and I think Gary can talk to this better, this is the same ISI as would be required by ASME but its analysis and looking for particular flaws is required for this rule.

So doing a plant-specific ISI is not trivial. You need to be an outage and you need lots of people on site. I'm not a utility guy so I can't give you a cost. But it's not something you just do over a weekend.

MR. STEVENS: But we're invoking - I mean what's required here is in ASME Section 11 Appendix

A exam, which plants have to do anyway. There are some -

MEMBER SKILLMAN: That's why I'm asking the question. So I see the column and I'm saying well, there are inspections that are required anyway so I don't know if this is piling on or this is a small increment to an inspection that is already required at some frequency be it every ten years or, you know, whatever it might be, or at your first opportunity before you intend to take advantage of this 61 alpha.

MR. STEVENS: Yeah, I think I would answer your question as this. As somebody that's intending to use this, I think there are some additional considerations they need to build into their examination, which you'll see here.

For example, verifying flaws aren't - axial flaws aren't connected to the surface. That may not be required necessarily by a traditional Appendix A examination that is required here by 50.61a.

So there are some additional considerations that some of the plants may need to build into their exam that they otherwise wouldn't. My opinion is that will add some time and cost but I don't think in the grand scheme of an examination it's that significant, especially given that these things are well planned out ahead.

The second part of it then is taking the results of that examination and interpreting them and analyzing and aligning the flaws that are detected up against the flaw distribution that was assumed and is delineated in the rule, and this is, you know, less - it's a couple days effort.

There's an example in the NUREG where we go through a sample calculation and, frankly -

MEMBER SKILLMAN: Would it fair to say that the plants that would likely wish to use this option are already well aware and that they are probably making plans for their future outages so that they've got the build-in reserve to do what they need to do?

MR. STEVENS: Absolutely. I think in the case of Palisades there is a lot of activity and planning and discussion prior to the inspection that happened earlier this year.

MEMBER SKILLMAN: Thank you.

MR. STEVENS: All right. And as I said, we're going to get into a lot more detail on that - you know, the requirements and the guidance we're putting forward on that as part of this discussion.

The next thing we want to talk to you about here was stakeholder feedback. Throughout the process of the last several years of putting this together we have reached out.

It's important that we got industry feedback and public stakeholder input on this. We have continually been open with the industry and the public on this - development of this reg guide.

We held three public meetings in 2011 that were specifically focused on RPV activities and in particular this reg guide, in particular the NDE side of this issue.

As a result of those meetings and other interactions we've had at ASME and places like that, EPRI's materials reliability program, or MRP, I provided a document which is listed here and I sent that to Chris from the committee earlier - MRP 334 - and they basically - that was kind of their feedback to us and they provided recommendations with respect to the technical issues associated on this topic for us to consider.

Specifically, there's a table in the front of that document where they had 15 specific recommendations or comments in seven areas.

We have addressed those comments in - back in Chapter 3 of our NUREG, item by item all 15, and, you know, EPRI's intent and the industry's as well as the reason we reached out on all this was try to reduce licensing and NRC burden and make submittals consistent and, you know, provide consistent levels of safety in these evaluations.

These are the seven areas of recommendations. It wasn't my intent to go through these in detail. These are not the specific comments. They are in the NUREG.

As I mentioned, in Table 3 of our draft NUREG 2163 we did address all of the 15 issues and I'll say that we basically incorporated adjustments to our work for all of that reason.

It was valuable to us. We did take some disagreement on a couple of the comments that were made but still we made adjustments in response to that comment in some of our work.

So this was valuable to us and I think it's going to serve NRC and industry well going forward to provide that consistency we're looking for.

CHAIRMAN BALLINGER: I think you agreed with, what, 11 out of 15 or something like that? It was a very high number. It was very - yeah.

MR. STEVENS: Yeah. And of the other four, even though we took some disagreement to the comment, again, I think we made changes still, maybe just not in the direction that they were commenting.

MR. SHACK: A fairly big item to me is seven, where they had a simplified process for dealing with a flaw distribution that didn't match the rule, which I suspect is something that's likely to happen in practice.

I mean, my expectation is that your flaw distribution will be conservative most of the time. What you'll find is they'll be somewhere where you have a deviation and it seemed to me that they - you know, that is something where a simplified process would be helpful rather than a full fledged PFM calculation and - I mean, they gave you one in Appendix F, which you apparently don't find satisfactory and do you have specific objections to the way that was done?

I mean, in some ways it was it was done similarly to the way you came up with the flaw table in the first place.

MR. KIRK: Well, we came up and we'll be discussing this on agenda item nine - we came up with a simplified form which addressed our concerns as well as came up with a simplified approach.

MR. SHACK: Is that position four?

MR. STEVENS: Position four. I need to look at the reg guide because I don't remember numbers but I think it is.

MR. SHACK: Okay. But that doesn't really address the flaw -

MR. STEVENS: Yes, it is.

MR. SHACK: I mean, that's an embrittlement problem but it doesn't really address the difference in the flaw distribution, which strike me as the more likely event to occur.

MR. KIRK: We don't - we didn't incorporate a generic way to deal with flaws that don't meet the flaw tables.

CHAIRMAN BALLINGER: That's why I was kind of pinging on you about the Palisades and Beaver Valley and how - where they were likely to get hung up.

MR. STEVENS: Our experience, and we did look at better than a dozen flaw evaluations or - I'm sorry, inspection results for plants that we were able to look at through submittals or part of the review of the NRR activity associated with extending RPV inspection from 10 to 20 years, and our experiences we have yet to see any plants that challenge the flaw tables in this rule.

So another reason I think we chose a realistic not to address that comment is first off is a lot of different possibilities on flaws that could exist that might challenge those limits, and then second, we just didn't see - it seemed to us that to have a fair probability that that would occur so we didn't see the need to spend the resource to chase that because our experience was we don't see people having trouble satisfying the flaw regs.

Any other questions on - as I said, we're going to get into the guidance which -

MR. SHACK: Like I said, partly that may be the way you've chosen to interpret the NDE exams. Since you don't have to correct for probability of detection as a mandatory thing I get a whole lot less flaws if I don't have to do that.

MR. STEVENS: That is correct.

CHAIRMAN BALLINGER: The POD is built into this.

MR. SHACK: No.

MR. STEVENS: No. It's not a requirement

that they -

MR. SHACK: We'll have that discussion a little later.

MR. STEVENS: Yeah, and we'll talk about also the capabilities of NDD and how they might size those flaws and where that puts them with respect to these flaw regs.

MR. KIRK: Okay. So actually this one is very easy is basically what the construction date limit says is that we wanted to narrow the population of plants to which this rule could be applied without further justification to the population of plants that we modeled.

So it's set up to ensure that we don't have any new plants that are automatically applying the rule and that's really all it says.

So any new construction plants would need to provide additional justification that the rule applied to them.

MR. SHACK: They're not likely to -

MR. KIRK: Well, no. No. There's - if -

CHAIRMAN BALLINGER: They're not likely to have an embattlement problem ever.

MR. KIRK: As - yeah. As one of my NRR colleagues said, if any new plant has a lot of copper in it - well, then he said something that I shouldn't repeat.

So yeah. Yeah. Yes, this stops new plants from using the rule. The new plants have to use the old rule, which is a little odd.

But there's no reason that they would ever need to use the new rule. So next. So now is the extra three columns in the spreadsheet discussion. Okay.

So the goal here - the goal of both the checking the embrittlement trends and, getting a little ahead, checking the flaw population is simply to say these are two things we can measure - the level of embrittlement and the number and size and location of flaws in the vessel.

Look at K equals sigma square root pi A and quickly decide that those - both of those things are very important variables in the analysis. So since we can measure them and we can check them it seemed prudent to do so.

The surveillance checks are far more simple than the flaw population checks. I'm glad Gary is doing the flaw population part.

So all we're doing here is trying to see that the plant-specific surveillance data is following the trends that were used in the development of the rule.

So next slide. I've provided just cartoons and not equations. The equations are in the rule and are really fairly simple but the equations are checking for three types of deviations of the data from the generic embrittlement trends in the rule.

One is the mean test where you - a set of data could fail the mean test if they were - statistically it would fail the mean test if either the data are systematically shifted up from the embrittlement prediction so the embrittlement prediction is too low or it shifted down.

Of course, regulators - so we only care if the embrittlement prediction is too low. The slope test, like its name indicates, tests for a different rate of evolution of embrittlement with fluence and the outlier test, again, as the name implies, tests to see if there is one data point that's significantly above the expected trend.

Standard statistical techniques and cutoffs are used to implement all of these tests and in the - in the limits, which you'll see, I think we used, like, 99th percentile.

It's really a fairly high bar to defer to the plant-specific data versus the generic data, which really, you know, if you decode that reveals the staff's confidence in the generic trends that are being used.

Just also a note here - that to the extent that, say, I'm operating Plant A and I have weld one, two, three, four, but weld one, two, three, four is also in Plant B, I'm also obligated to use that data and that's - in the nuclear materials lingo we call that sister plants. I don't know why they're sisters. That's what we call them.

MEMBER BLEY: How often do these tests have to be done? Is there a limit on the minimum amount of fluence between the tests? I mean, you don't want people doing this -

MR. KIRK: These are - I should have said that - these are the data that are collected as part of the 10 CFR 50 Appendix H mandated surveillance program.

So and that program has varied over the years because it depends on the ASTM standard in force when the plant was originally licensed. In general, looking at the fleet you'll have between three and five data points spaced over the life of the reactor and in general they'll be out to fluences that are 1.5 or in some cases a little bit more times the end of license fluence.

So, you know, that's the other thing and that's why we tend to defer to the generic trends is there's really just not that much plant-specific data to go on, in most cases.

If in some other universe, which we don't exist in, there was a hundred plant-specific data points I think, you know, quite clearly we'd just use that trend. But that's not what we have.

So, really, we're looking here for the limited data - we're looking at the limited data that we have to flag big inconsistencies between the embrittlement trends in a particular vessel weld plate forging with what we use.

MEMBER POWERS: Mark, do you happen to remember what test you used for detecting outliers because outliers are -

MR. KIRK: I - no. It's written in here.

MEMBER POWERS: Yeah. I can look it up.

MR. KIRK: Yeah. And you're - I went through a lot of that in recent ASTM work. You're right. There's way more than one outlier test. Absolutely.

MEMBER POWERS: Yeah. I mean, it's very common.

MR. KIRK: Yes.

MEMBER POWERS: I mean, especially on any kind of mechanical test it's just endemic to the testing.

MR. KIRK: Yes. Okay. So - okay. So and these were some of the - well, the first test - sorry. Too many briefings in one day.

In the guidance we provide certain - I'll say standardized procedures to allow licensees to correct for failure in these tests. Those are illustrated here.

In the case of a mean test failure, you're just required to add a factor which we called ADJ for adjustment, not adjective, which is the amount by which you failed the test.

You add that on to your embrittlement level and carry on. In most cases, a mean test failure would indicate, you know, at least to me, having looked at a lot of this data, that your unirradiated RTNDT value was wrong - was not appropriate for the data.

For the outlier test, we permit if the outlier happens to be on a low fluence data point, since in all cases here we're interested in the high fluence end, if you're at less than 10 percent of the fluence that you're evaluating for and that's your outlier, you're permitted to discount that point and then there's no diagram here for what to do with the slope test.

It just indicates that if you use the greater slope indicated by the data the staff would probably be okay with that. Again, this is something and we - in the staff discussions we went back and forth about this a lot as to whether there should be rote procedures or just leave it up to the licensee and things that are written in the NUREG, I guess, express what I'll say is, you know, my personal view and I think it's shared by several people, is that if one of your few surveillance data are flagged up as being statistically unusual by any of these tests, you know, I think just as a matter of good practice you should be looking at them.

You should - you should not just be adding a value and moving on. It's a flag that something's going on.

MEMBER BLEY: The troublesome outlier would be one out on the end.

MR. KIRK: One at the end and we're not permitting that to be discounted.

MEMBER BLEY: What are you doing with that one? Because you don't know if that's the indication of a suddenly increasing slope. You don't know what the heck's going on.

MR. KIRK: That would be - we don't -

MEMBER BLEY: Or it could be an anomaly.

MR. KIRK: - we don't have a procedure to -

MEMBER BLEY: You just have to look at it and -

MR. KIRK: That should be looked at and I think that's the right -

MEMBER BLEY: Fair enough.

MR. KIRK: - that's the right thing to do.

MEMBER BLEY: Yeah, I agree.

MR. KIRK: I mean, that's what we should be looking for.

MEMBER BLEY: Because you don't know anything about it except it's either indicating a new trend or it's an anomaly of some sort.

MR. KIRK: As sometimes happens. So I think that's the end of that section.

MR. STEVENS: ISI and NDE.

MR. SHACK: This is a break or -

MR. STEVENS: Yes, actually. We're a little bit ahead of schedule. Do you want us to continue or take a break now?

CHAIRMAN BALLINGER: We're scheduled for a break at 3:00 and so we have plenty of time, I think.

MR. STEVENS: We'll keep going. This is - we're on - going on to slide 36 now, Chapter 6 of the NUREG and position three of the reg guide talks about NDE requirements - nondestructive examination requirements.

So these are the two flaw tables in the rule. There's two because there's one for plates and forges and there's one for wells, and what these tables basically give you are the cumulative number of allowed flaws for a given, what's called here through-wall extent.

Like, I would call it depth but through-wall extent is the terminology. And the basic requirement here is to take plant-specific NDE or ISI results and to demonstrate that these flaw - you're within these flaw distributions which were assumed in all of the probabilistic work that goes behind the alternate rule and a very simplistic statement. So very simplistically stated, that's what we're trying to do.

What is required by the rule in terms of NDE and what is optional? What's required is that you do a qualified examination in accordance with ASME Section XI mandatory Appendix A.

As has been pointed out earlier that's already a requirement for plants to do so it's in a way nothing new with this rule but it is a requirement of the application of this rule.

And a secondary requirement is that any axial flaws that are greater than .075 inches in depth of through-wall extent that are located at the client base metal interface those need to be verified that they do not open to the inside surface direct to pressure vessel, and we'll get into how they might do that.

As Mark showed in his earlier slides with the through-wall cracking frequency, importance of axial flaws I think you can understand why we've got that requirement here.

What is optional, as was also pointed out earlier, is NDE uncertainty and probability of distribution. The rule allows you to apply those but it is not mandatory.

MR. SHACK: And why is that?

MR. STEVENS: Generally speaking - we're going to get into that - the rationale was that NDE techniques tend to oversize the smaller flaws which would elevate those into the larger bins or, I guess, going back to large tables - larger size bins which are lower on those tables which have a lower allowed number which therefore is conservative.

MR. SHACK: But neglecting the POD is nonconservative and somehow you've made the judgment that one is greater than the other.

I mean, considering the not so ringing endorsement of this inspection you got from PNNL I would be a little surprised that I wouldn't take the slightly conservative route and say that you have to correct for POD.

MR. STEVENS: So that's a fair comment and I guess I'll offer a couple more. You're right, so POD would increase the number of flaws. We're going to get into this a little bit too.

We're actually going to touch upon it. But as a plant that might not pass the flaw tables might get into a more detailed plant specific assessment, in Appendix C of the NUREG we have this Bayesian updating where we looked at PODs.

One of the reasons - well, one of the things we've done over the last several years is EPRI updated their PODs for vessels and we've looked at that.

In all the assessments we've done as well, as I mentioned earlier, the more than a dozen plants we've looked at, even with that we still don't see plants coming close to challenging flaw distribution that was assumed for this work, which is thousands of flaws.

MR. SHACK: But as Mark would say, you know, doing the Bayesian update doesn't seem to me that big a deal. It's a - you know, it's more work than the statistical check but it's certainly not a PFM analysis.

When I look - my first - when I first read the thing I was sort of wondering well, you know, why not just do the POD on the data and be done with it and that would be, you know, give me my estimate. That would be a very flaw - a plant-specific flaw distribution.

When you do the Bayesian update with the V flaw distribution as your prior, you're really kind of discounting the plant-specific thing and building in V flaw which I think, again, considering the not so ringing endorsement is probably not a bad idea.

I mean, you know, it incorporates everything we understand about flaws in vessels and sort of yeah, it biases it in a conservative way but it seems to me because we have uncertainty about our NDE, I mean, I can see making the argument for either using the POD and correcting for that or doing the Bayesian update. I can't see the argument for ignoring completely.

That just - you know, either - the other two approaches strike me as reasonable. In my current state, I like the Bayesian update. But doing nothing just doesn't strike me as the right thing to do.

MR. STEVENS: So I'm going to respond - and I don't know, maybe this is a copout - but so I agree with what you're saying. The guidance we're writing is for the rule, which is already published which says what it says and it doesn't say that that has to -

MR. SHACK: Well, it tells you how to -

what we're discussing now is how to determine the distribution of flaws. It doesn't tell you that you have to do it one way or another. I mean, that's what the reg guide is telling you how to do.

I'm not suggesting we change the numbers in the tables at all. I think it's a question of how we get the numbers to compare the numbers in the tables too.

MR. KIRK: I think what Gary's reflecting on is that the language in the rule, rightly or wrongly, states that you don't need to account for POD and probalitic correct sizing.

You don't need to account for NDE uncertainty when comparing to the table. I don't recall the specific language. We can look it up.

But that's not a - that's not a requirement of the rule. And, again, you're certainly welcome to take issue with that but, yeah, I think - I'd echo Gary's response.

We're writing a reg guide for that rule that has that guidance. If there's a question about - you know, we're writing a reg guide for that rule -

MR. SHACK: Test results may be adjusted

to account for the effects of NDE-related uncertainties.

MR. KIRK: May be. May be. Not shall be. I hate these discussions.

MR. SHACK: The methodology to account for NDE related must be based on - boy, that's a - maybe gets into the rules.

MEMBER BLEY: So does it say anything about that in our letter? I can't remember.

CHAIRMAN BALLINGER: Not the original letter.

MEMBER BLEY: No, the one -

MR. KIRK: Your letter - your -

CHAIRMAN BALLINGER: The one in 2009.

MR. KIRK: The ACRS's letter predated the rule one, I'm sure.

MEMBER BLEY: Yeah, I think we were sort of blessing the approach. I don't know that -

CHAIRMAN BALLINGER: But that was the earlier letter. We wrote a letter in 2009 on -

MR. KIRK: Right. The actual language of the letter -

CHAIRMAN BALLINGER: It was a draft of the rule.

MR. KIRK: Well, we've made mistakes.

MR. STEVENS: So just to finish my thought in response, we didn't put that - didn't make that part of the guidance because we don't - our interpretation is that's not a requirement of the rule so therefore we can't force people to do that and then furthermore our investigations, some of which are in the Bayesian update in Appendix C as well as other assessments we've done of flaws, we've not ever obtained a result that challenges these flaw distributions that would cause us to challenge what the rule says.

MR. SHACK: Well, I think there's one example in the PNL report where they do a comparison with a Shoreham vessel where they get something in one of the bins slightly over.

Now, again, Shoreham's probably going to have more flaws than any of your PWR vessels so that doesn't negate your comment that you - I mean, I would think that would be true.

I mean, I certainly, because of the conservatisms you built into the V flawed thing, that I would expect these things to be conservative.

Most of the time what I would be most concerned about is, you know, one bin that just happens to have a few more flaws in it than the rule allows. But, again, not correcting for NDE uncertainty.

MR. STEVENS: It's a good comment.

CHAIRMAN BALLINGER: I have a question from Dr. Riccardella.

MR. KIRK: We have a comment from Professor Madeiras, the University of Maryland, who helped us with the - helped us - did the Bayesian update.

DR. MADEIRAS: Yeah. I did the uncertainty analysis Appendix C that you will see there. So they asked me to come - actually so I apologize I didn't get the first part of your presentation.

But go back to your comment about the uncertainty, the POD and the sizing uncertainty in Appendix C was formally factored into the calculation. It's not that it was ignored. It is true that the V flaw -

MR. SHACK: No, no. In Appendix C it's included.

DR. MADEIRAS: Yeah, it's included but it's not included in what they -

MR. SHACK: Right.

DR. MADEIRAS: - if they filled the table then they go there. But if they go to Appendix C then that's counted.

MR. SHACK: I don't - I never had any argument with that. It's the fact that you can do it without correcting for it in the first place that boggles my mind.

DR. MADEIRAS: So and it is true that if you do some sensitivity analysis with the - with the model - with the Appendix C model in cases that you have a lot of reporting a lot of flaws around .075 and a little bit larger, you get like a hundred flaws measured by NDE then it is possible that you would violate some of others because of -

MR. SHACK: Yeah, but I noticed in your sensitivity analysis that you included in C and D you never did do the one where you just did the POD correction.

DR. MADEIRAS: Right.

MR. SHACK: Which would have been interesting.

MR. STEVENS: But the rule is the rule.

CHAIRMAN BALLINGER: We have a question from Pete Riccardella via email. Is the absence of surface penetration typically demonstrated by its surface exam PT or ET or by the original UT? I'm just reading the email.

MR. STEVENS: Okay. So there's nothing in the rule that specifies how you do that. I'll just say that in the recent Palisades exam they used eddy currents to verify the absence of surface cracking and in our guidance we've identified eddy current as an acceptable form of doing that but we haven't stated it's the only way of doing that.

There could be others and I'm not aware of any others that folks might particularly use.

Moving along to slide number 18 - is that 18? I can't read it.

MR. KIRK: Thirty-eight.

MR. STEVENS: Thirty-eight. How these requirements are invoked - so the - what this table is trying to show is the description of the flaws that we're looking for on the left side and how they were assessed was on the right side and the increasing risk significance from the top of the table - I'm sorry, from the bottom up.

So first thing are the flaw that we're most interested in with regard to risk significance is the surface connected ID flaws that have a depth greater than .075 inches, as you mentioned.

If such a flaw were to be found they would need to have a flaw-specific assessment of through-wall cracking frequencies - their contribution through-wall cracking frequency performed.

The next level down in risk are embedded within the first inch and I think what the rule actually says the first inch or 10 percent of the wall thickness, whichever is greater, and those need to be assessed against the flaw tables and if the flaw tables are exceeded they needed to be - they also need to be assessed then for through-wall cracking frequency contribution.

The next level down are those flaws beyond the one-inch or 10 percent criteria but within the - and are three-eighths fraction of the wall thickness from the ID and those need to be assessed to be acceptable. Actually, all flaws need to be assessed to be acceptable in accordance with Section XI.

But these need to be assessed against the acceptable criteria of table item 35101 in Section XI of the code which is for vessels, and then if the flaw exceeds those acceptance criteria they also need to be assessed for through-wall cracking frequency. The code would also require a flaw variation to be done in that particular case. That goes without saying.

And then finally any flaws that are embedded and beyond the three-eighths inner portion of the wall thickness no assessment is required beyond what's required by Section XI of the code. Those flaws have insignificant contributions to risk in the PTS assessment.

MEMBER BROWN: Can I ask a question? Is volumetric test data what you talk about when you're talking about the examination - the POD probability detection?

MR. STEVENS: Yes.

MEMBER BROWN: Because there's some stuff - this just happens to pop up in one of the documents we got - talked about the volumetric test data, adjustments made to the test data to account for the NDT related uncertainties as described in this section.

So he talks about licensees accounting for NDE related uncertainties and that's in the rule, I think.

MR. STEVENS: Yes. So we're going to get -

MEMBER BROWN: That's why - you answered

Bill, I thought. Maybe I misunderstood the answer is that there is no requirement.

MR. STEVENS: There's no requirement but a licensee is allowed to if they choose to. As you go through this guidance we'll go through an instance where a licensee may choose to apply those uncertainties.

So, for example, if a plant went through a comparison of their NDE findings against the flaw tables and they did not meet those flaw limits they could then go and apply NDE uncertainty and it's possible after doing so that they might meet the flaw limits.

And that may at first sound a little contrary to your thinking but if small flaws are oversized they tend to be elevated into the larger bins that have a lower allowable number of flaws.

So if you - if you took account for that correction by taking into account the NDE uncertainty which would reduce the size of the flaw you could drop it to a bin with a higher allowable and that could be acceptable and that's allowed by the rule. It's not required. It's allowed.

MEMBER BROWN: Okay. The licensee shall

verify that the requirements at paragraphs E, E(1), E(2), E(3) of the section have been met. Must submit within 120 days after completing any examination of reactor vessel built lining materials as specified in the ASME code, the adjustments made.

MR. STEVENS: Right. If they -

MEMBER BROWN: This says they must have - but you're saying if they do they must submit them but if they don't they don't have to.

MR. STEVENS: That's correct.

MEMBER BROWN: Because there's a lot of stuff in here in the -

MR. STEVENS: There's a lot of stuff on NDE uncertainty and NDE in general, yes. So it's not a requirement. But if - it's optional but if they choose to do it then you're correct, there are certain things they must do if they choose to go down that optional path.

This slide - the bottom line is that thermally-driven stresses produce greater risk significance for flaws that are closer to the ID. Therefore, the requirements are much more stringent for those flaws.

This is not a Kirk diagram. This is a

Stevens diagram, and this was -

MR. SHACK: Learning from the master himself.

MR. STEVENS: See what four years and eight months here has done to me? So this was my attempt - this is my attempt to try and pictorially represent two different things.

The dotted line - the black dotted line represents the Section XI process of doing an examination starting in the upper left, an Appendix 8 qualified examination, and what you go through to show acceptability of what you might find and that involves - you know, if you're interested the particular supplements in Appendix 8 are four and six that have to do with RPD and the inside surface and far surface and if you detect something you have an indication and you go through some initial evaluation in flaw sizes in accordance with your procedures and what you come out with are reportable flaws, the inspector might also kick out some things there which they typically call metallurgical or geometric reflections, things of that nature.

You know, things that are built into the geometry of the design that might cause a UT signal or a volumetric signal but they're not flaws.

And then what you go into in Section XI is the flaw proximity criteria and that criteria, in essence, if you have multiple indications that are close enough together you're to group them into a larger indication and it's what comes out of that process which the little dotted line circle Step A, combined recordable flaws, that's what we're saying needs to be evaluated and lined up with the flaw tables. So this chart is really meant to - and you have the red - it's not really a box - it's a weird shape polygon, whatever it is, that's the - that's what we're trying to indicate is, what, 50.61a cares about. Those flaws come out and get compared to the flaw tables.

The rest of the diamonds and squares on this page are the ASME Section XI flaw evaluation process that gets used which effectively is to take those recordable flaws, compare them to acceptance criteria. If you're less than that you passed - you're done.

If you exceed it you do a flaw evaluation and evaluate that for continued operation. It's acceptable. You're done with augmented examinations. If not, then you're doomed to repair or replacement.

So I think the message from this slide is we're trying to show you in that Section XI process at what point you extract information for use in the NDE world with the world - the alternative world.

This is another Stevens chart, although it is influenced by Kirk, and -

MR. SHACK: Namely, the subtle choice of colors.

MR. STEVENS: So -

MR. KIRK: Have you been speaking with my wife?

MR. STEVENS: This is the 50.61a process and what's in common with the prior chart is really just the top box - the green box at the top.

We're starting with a qualified Appendix A examination at Step A and out of that with a little dotted line oval from the previous slide is we're taking recordable flaws that are in the inner three-eighths fraction of the wall as we delineated a couple slides ago, in the belt line region of the vessel and we're going to assess those against the rule.

You might want to pull this slide out and set it by your side because I'm not going to go through every box on this slide here but we're going to go through these steps now in the following slides.

And what this flow chart is trying to do is this would say how you would apply the rule and the simplest path being right down from the green box vertically downward, you know, pass go, collect $200 or whatever it is.

In Step K you can apply the screening criteria and submit to NRR for review and approval. There are some red boxes which is you fail, don't pass go, go straight to jail.

Okay. So I'm going to pick this up really at Step D here and I've tried to isolate that out on the flow chart. The first few steps are just doing the axial flaw check regarding connection to the ID surface and then passing ASME code.

Then we get into Step D, which is the flaw assessment and this is taking your results and comparing them to the flaw data.

We give guidance and there's a sample problem because in the final analysis, at least in my more practical minded nature, an example works wonders so I went through a sample and it's a totally made up example.

It's influenced by some inspection

information that was provided to us generically from Westinghouse and I just went through that and worked an example going through here and basically the first step is to take the flaws that come out of the NDE exam and determine plate and weld flaws.

We get some questions here on but aren't your Section XI examinations focused on welds and the answer is yes but those examinations typically go two thicknesses on either side of the center of the weld of RPVs so there is some base material included, and at least the way in our guidance we showed is based on design drawings or in many cases ISI drawings of the weld.

It's just a geometry problem based on the UT report to determine whether the flaws are in the weld or in the plate and that's what we do.

We do - if the flaw gets close enough to the weld line then we don't get specific but we indicate in the guidance that there needs to be some consideration given to heat-affected zone issues there and generally speaking the weld tables and weld flaws are the more conservative of the two.

So at least if I were doing an evaluation if I got close enough to the weld I might treat it as both a plate and a weld flaw if there were any questions on whether that part of the plate were affected by welding. It's - next thing is to identify those flaws on the either 1 percent or - 1 inch or 10 percent of the weld thickness.

Again, there are other flaws beyond that in the inner three-eighths that need to also be assessed and they need to be compared to the acceptance criteria of the ASME Section XI from Table WB 35101. That's a requirement no matter what.

But what we require here is that they must pass those acceptance criteria whereas the ASME code wouldn't require them to pass acceptance criteria provided the follow-on flaw evaluation were done. Here we're saying they must pass the acceptance criteria.

Okay. Now we'll talk about NDE uncertainties. So the first bullet we already stole my thunder there. NDE uncertainty may be accounted for but is not required.

We do provide guidance in Chapter 6.4 of the NUREG on accounting for NDE uncertainty and also elements and some NDE techniques that might be considered as a part of the examination and I kind of categorize it as little tweaks and adjustments that licensees may make to their otherwise scheduled Appendix 8 exam that might enhance it for use with this rule and that is based on the PNNL report that Dr. Shack already identified.

And then what this might do - and again, as we talked about since most of the flaws that we've seen are relatively small there's a tendency for NDE and ISI to oversize those flaws and kick them into the lower bins and larger - which are larger flaw sizes with lower allowable.

So it is feasible that applying NDE uncertainty could kick those flaws into the smaller size bins with higher allowables and so a licensee would be able to apply NDE uncertainty, reapportion the flaws and compare then against the table and if they were within the limits of the table they would pass. They would be better.

MR. SHACK: Can he just do flaw sizing errors and forget the POD?

MR. STEVENS: Possibly, although we might ask an REI on that one. So what this does is it - the as detected and as -

MR. HARDIES: This is Bob Hardies. No,

the rule doesn't make you do the POD evaluation. When we wrote this rule we knew where the flaw distribution came from.

It came from destruction of a few square meters of vessel material and every flaw - every indication - everything they found metallurgically destroying it and ultrasonically examining was characterized as crack and put into this distribution. So we knew that a lot of those flaws were pores.

A lot of the flaws were little slag inclusions and so we came into the rule making with the understanding that that flaw distribution that was put in we believed to be very conservative.

What we wanted with this NDE step was that plant to perform NDE to make sure that they weren't an outlier.

We really expected because we had looked at a lot of plant NDE of vessels that the number of flaws in the vessels would be extremely small compared to this distribution and subsequently we've seen a lot of vessel exams and the number of flaws in the vessels that are actually detected are very small compared to this distribution.

So this whole test was kind of like a ball park - look to see if you're wildly out of it or if you even approach that distribution that's in V flaw to do your vessel exam you're outside of the bounds of what we would have expected. So that's what we really wanted them to look at.

So we didn't have them design some special test to do it. We intentionally said use the Section XI exam. We knew those - that exam undersized the small flaws and so would be overly conservative and we allowed them to get out of that - over conservatism in the rule and we recognized that there was a problem at the small bin size with POD but, again, we're just trying to get an indication where we really think that the actual vessels have much fewer flaws than were in the V flaw distribution.

MR. STEVENS: Okay. And then we - accounting for NDE uncertainties can get more complicated with POD going to Bayesian updating as we talked about in Appendix C and that works in prior flaw distribution from V flaw as well as plant-specific analyses and all that.

Se when get into that form of guidance our expectation based on what we've seen is that we wouldn't expect to see that used.

But it's there because of the work we did to look at the issue you brought up earlier. So we put the guidance in since we had it.

MEMBER POWERS: What is - what happens if you get the kinds of things they're seeing in these weld plates in this detection?

MR. KIRK: They would fail the table.

MEMBER POWERS: Yeah.

MR. KIRK: Because there would be so many. I mean, we don't -

MEMBER POWERS: By a big margin.

MR. KIRK: Yeah. We don't - there's - well, first off, I should just say the likelihood of finding those based on the inspections that are done in the United States is somewhere between slim and none because we inspect only the welds, which is where these flaws are not.

But if they were found they would trip the tables because they would be numbering in the thousands and we don't allow thousands of flaws.

MR. STEVENS: Okay. So that's true for the in-service examinations and this is another topic we could talk about for weeks but in Section 3 in initial fabrication examinations at least we've seen are capable of finding those flaws and based on the interactions we've had with the industry there are no plants in the U.S. that's seen that kind of - those kind of indications, and Bob's going to say something more. I knew he would.

MR. HARDIES: I'm not sure they would fail the table because the table wants a through-wall dimension and these don't have very much through-wall dimension.

CHAIRMAN BALLINGER: They're laminate, right?

MR. KIRK: Yes. Yes. That's a good point.

MR. SHACK: It might be unlimited.

MR. STEVENS: They might be in bin one, which is unlimited. So what happens - well, fundamentally if a plant would meet Mark's statistical checks and they passed the flaw table they could use criteria - alternate criteria in the rule.

If the flaw table comparison is unsuccessful then the licensee can perform additional evaluation to try and demonstrate acceptability and that could take a variety of forms.

We have included guidance on two that we think if they're going to be - if the situation's going to be encountered they're the most likely to that would provide helpful guidance.

The first one we cover in a part of - a subsection of Chapter 6.2 is what we call precluding brittle fracture and basically here what we did is we just looked at the lower bound PTS transient temperature of 75 degrees and we established a criteria based on upper shelf behavior of RTNDT plus 60 being less than that - less than or equal to that value. It's a very simple check.

And so what that amounts to is to demonstrate that the flaw-specific RTNDT values are less than or equal to 15 degrees, which is 75 minus 60, and what that means for a flaw-specific RTNDT is to look at the location of the flaw both in terms of whether it's in plate weld, where it is in the belt line and through the wall thickness and the specific material properties of that break or weld and the fluence at that location and calculate the appropriate RTNDT for that flaw.

The other way to solve the issue would be to calculate through-wall cracking frequency and that's through plant-specific probabilistic fracture mechanics analysis and here again many, many, many possibilities.

We don't get into the specific details of such a plant-specific probabilistic fractional mechanics analysis but we give guidance on what those analyses should consider - the elements that should be built into those evaluations, and that guidance is consistent with the elements that were built into the probabilistic fracture mechanics analyses done in support of this rule.

CHAIRMAN BALLINGER: I have a hand-delivered note.

MEMBER STETKAR: He was asking you because you're the expert.

CHAIRMAN BALLINGER: Oh, you want me?

MEMBER STETKAR: Well, I wanted to ask somebody that would tell me the truths in here.

CHAIRMAN BALLINGER: What is the RT for the unirradiated metals. I'm assuming that you mean RTNDT?

MR. KIRK: Yeah. Basically, this is saying if you happen to have found the flaw - an indication that doesn't meet the tables, if it's in a region of very low fluence, meaning essentially unirradiated, you might be able to screen it out. That's what it boils down to.

MEMBER POWERS: I mean, what you're saying is unirradiated material is basically 15 degrees out.

MR. KIRK: Or lower. Or lower.

CHAIRMAN BALLINGER: In newer ones it's a lot lower, yeah.

MR. KIRK: Yeah. So it's just - I mean, we were - we were trying - and so it's kind of fancy but it's actually pretty plain - is we were just trying to say if the fluence is low enough and obviously we're being fairly conservative in that then the fact that there's a flaw there that doesn't meet the tables the 50.61a table is not - you still have to - you always have to comply with ASME but we'd be okay with it in this context if it meets ASME and it would have had to or you wouldn't get your code stamped.

MR. STEVENS: Submittals - regardless of whether you - well, however you conclude you can apply the rule requires a submittal to NRC for review and approval by the director of NRR. So use of the screening criteria, however you got there, requires a submittal.

For plants that fail the screening

criteria, then plant-specific PTS assessment is required. What that might be or what form that might take we don't get into that in our guidance.

We don't provide anything on that and that also must be submitted to NRC for review and approval. There are subsequent requirements - that is, after you submit your approved use rule there are subsequent requirements defined in paragraph D of the rule and I just note those here that they need to be followed, just as a reminder, and they're pretty well spelled out in the rule itself.

Any questions?

CHAIRMAN BALLINGER: Is this - we're close to 3:00 o'clock. Is this a convenient place to take a break or can we finish this by 3:00?

MR. KIRK: This section?

CHAIRMAN BALLINGER: Yeah, I think - okay. We've made an executive decision here.

MR. SHACK: I'm not an executive but I'm taking a break.

CHAIRMAN BALLINGER: He's taking a break. So we're in recess for - until ten minutes after 3:00.

(Whereupon, the above-entitled matter went off the record at 2:51 p.m. and resumed at 3:09 p.m.)

CHAIRMAN BALLINGER: Can we reconvene please? Whoops, we lost somebody. Well, you're on your own. Are you on or is he on?

MR. STEVENS: He's supposed to be.

CHAIRMAN BALLINGER: He's supposed to be? Whoops.

MEMBER STETKAR: Rule number one, before you reconvene a session make sure the speaker is -

CHAIRMAN BALLINGER: But he was here a minute ago.

MEMBER POWERS: Yeah. Well, a minute ago doesn't count when you reconvene the session.

MEMBER STETKAR: Actually - no, I was going say rule number one is make sure you have another living breathing ACRS member sitting at the table. Rule number two is make sure you have your appropriate minder in place. Rule number three is make sure that you have your presenter sitting up front.

CHAIRMAN BALLINGER: We will have a moment of silence.

MEMBER STETKAR: Actually you may want to go off the record.

CHAIRMAN BALLINGER: Okay. So that was meant in the kindest way.

MEMBER SKILLMAN: Mark, you're on the record.

MR. KIRK: Thank you. So one of the things that the rule includes is alternative limits on embrittlement and this is really, I think, put up to be more complicated than it is, is that as I related before the curve shown on Figure 47 are the basis for the reference temperature limits in the rule.

You set your limit on total through-wall cracking frequency of one times ten to the minus six and then you add up the various contributions.

But in the rule, of course, it's tables that are limits on reference temperature and in order to invert the equation easily what we did is take the simplifying assumption that the maximum reference temperature in the circ weld was limited to one times ten to the minus eight, not one times ten to the minus six, just to make it a two parameter problem rather than a three parameter problem.

If it's a three parameter problem then the response surface looks like this and it's extremely hard to put that in a finite table in the rule.

So really all this part of the rule allows you to do is say you are the circ weld limited plant that we were talking about before and you happen to be beyond the limits of the tables which were the circ weld.

I don't know if it's in the rule but it's certainly in the tech basis for the rule. There's a little footnote that says the circ weld limits correspond to one times ten to the minus eight rather than one times ten to the minus six.

If you happen to go beyond that, you are permitted to simply use this formula to sum up the various real cracking frequency contributions and as long as you're less than ten to the minus six you're fine.

So it's a completely equivalent analysis. It's just expressed in a different way and based on - I can add that based on the information that we have nobody's likely to meet this.

MEMBER SKILLMAN: Mark, is that, if I can call it such, the integrated canopy - is it uniform back on the circ weld at 150 - the whole way back to the right?

MR. KIRK: Is it flat? Yes.

MEMBER SKILLMAN: Is the bottom flat?

MR. KIRK: Yes.

MEMBER SKILLMAN: Thank you. Got it. Okay.

MR. KIRK: Yeah. Really, the only place where you get into - if you happened to be so unfortunate as to have a situation where the reference temperature for all three of the circ weld, the axial weld and the plate were all high then you'd get into this sort of corner region where they'd each be more limiting than the individual constituent parts. But in many respects this could be idealized by a box.

MEMBER SKILLMAN: Let me ask one more question. For a plant that would make an application to use 61 Alpha, would that plant end up with some cousin of this curve in their tech specs?

MR. KIRK: No. No, because the only reason they'd be using this curve is if they're in a very unusual situation. They -

MEMBER SKILLMAN: Or for evaluation.

MR. KIRK: Yeah. Yeah.

MEMBER SKILLMAN: Okay. Thank you.

MR. KIRK: Just for evaluation. So that's really all this is. It's saying we permit people to use the formula that's shown at the bottom of Page 48, which of course there's - each term has its own values that are exponentials.

We allow you to use this formula in lieu of the referenced temperature limits in the table but they're totally equivalent because the reference temperature limits in the table are determined from this point. That's it on that section.

MEMBER STETKAR: In principle it's in operational limits because it's pressure temperature curves. They're not in tech specs either.

MEMBER SKILLMAN: It would show up, yeah. See, here the cool down limits are in your tech specs.

MEMBER STETKAR: Yeah, this wouldn't show up directly but it -

MEMBER SKILLMAN: It would be a cousin of the -

MEMBER STETKAR: - it could instantly give the limits for -

MR. STEVENS: They would enter that calculation using end of life.

MEMBER SKILLMAN: NDT.

MR. STEVENS: - ND - right.

MEMBER SKILLMAN: Or exposure. Exposure, yeah.

MR. STEVENS: Whatever they're currently

licensed to end of life.

MEMBER SKILLMAN: And where that would really show up is in your heat up and cool down and your allowed operating window for backing the plant down and for taking the plant down.

MR. STEVENS: Slide 50 - where are we with this - regarding the draft reg guide - well, both documents have received program office reviews, that being NRR and NRO - all of those comments have been addressed and incorporated into the documents.

With respect to the reg guide, well, both documents were provided informationally to OGC back in June but OGC has not performed review.

That would come after this review is completed. So I put some schedules here and I've asked, you know, to say that these are minimums - the best case scenarios.

You know, realistically after this - after your review is completed and depending on the comments received or whatever or any of the adjustments we might make we're looking about six weeks before we would go out for public comment to go through the process and that would include four weeks for OGC review and, again, it depends on what kind of comments we might get back from OGC.

We are intending to send both of these documents out for public comment in tandem at the same time as opposed to separately. So there is a little bit of a - at least what I've found is, you know, the folks involved - different organizations involved and they're saying okay, we don't typically do that so there's a few extra lessons we've got to push to make that happen.

But best estimate schedule that we can see right now, given there's no significant delays in addressing comments is that we'd go out for public comment, which would be a 60-day period in February and we would hope to publish these next summer.

MEMBER STETKAR: I know this is a dangerous question to ask but from many interactions you've had do you anticipate extensive public comments or is that - you don't have to answer that.

MR. STEVENS: Well, so in theory no, because we had significant interaction with the public. However, I just - I had a NUREG that went out earlier this year that had probably even more interaction with the public and I received more than 200 comments on that.

MEMBER STETKAR: Okay.

MR. STEVENS: So I don't know.

MEMBER STETKAR: Yeah, I mean, it's always unclear. I was just trying to get a sense of where you might think you're going.

MR. STEVENS: I think we've been through this a lot, at least with the industry. So I wouldn't expect significant comments there. What other stakeholders we might pick up that's impossible to say.

We have no surprises in these documents from all of our interactions with the industry. We have two submittals in-house and from what we can see in all that there's no surprises anything. So we don't expect any hangers. That's all we have.

CHAIRMAN BALLINGER: Thank you very much. Can we go around and see if there are comments from the members? Bill?

MR. SHACK: Well, I understand the rationale now for why they're - it's a maybe rather than a shall. I'm not sure I'd agree with it but at least there is a rationale for it.

MEMBER SCHULTZ: I have no questions.

MEMBER SKILLMAN: None. Thank you very

much for a thorough briefing - very thorough. Thank you.

MEMBER POWERS: You did a very nice briefing. Just a very nice briefing.

CHAIRMAN BALLINGER: Nothing from me.

MEMBER RYAN: Nothing from me. Thanks very much for your time and talent.

MEMBER BROWN: I agree. Thank you very much. Very informative.

MEMBER REMPE: I agree with my colleagues about a very well done presentation. I have no additional comments.

CHAIRMAN BALLINGER: Comments from anybody in the audience?

MEMBER REMPE: Pete - don't forget Pete.

CHAIRMAN BALLINGER: Oh, well, he's not in the audience - this audience. Pete, are you there?

MEMBER RICCARDELLA: I'm here. I'm good. Actually, this was a very interesting way to follow the meeting.

MEMBER STETKAR: Sure. Don't make a damn habit of it.

CHAIRMAN BALLINGER: Is there anybody else? Is this line the same as the public line? Is there anybody else out there if you'd make yourself known, please.

MR. KEEGAN: Hello. Can you hear me?

CHAIRMAN BALLINGER: Yes. Can you give us your name? Can you give us your name?

MEMBER STETKAR: You've broken up. I don't know whether you're using a cell phone.

MR. KEEGAN: I'll try to get off my speaker. Just one moment. Hello. Okay. Yes. Hello. This is Michael Keegan with Don't Waste Michigan.

I've been tracking the embrittlement issue for 20 plus years at Palisades and I see there is their embrittlement - original embrittlement standards in 1981 and the standards get relaxed. We have six relaxations, changes of methodology.

It seems that the regulators are willing to do some kind of mental gymnastics - anything it takes to allow them to continue operations. I really had problems following what went on.

I did follow it. I did track it. But I had problems in believing in the validity of the research design. It seems rather hodge podge. Everything can get to yes and I hear a lot of computer modeling and what I'm seeing is garbage in garbage out and just - if the new methodology doesn't work, if the value can't be met then there's another set of things they can do.

There is null hypothesis - there's no possible hypothesis. Everything is yes. Everything leads to yes. If we get a no we eliminate the unvariable. We put some other stuff in the equation.

It's really poor research design. It really smacks of different quality assurance and I don't see that and I don't the integrated plan from start to finish. All I see is an industry that's in dire straits.

If this - if the reactor is under standard from PTS we undeniably will have a Chernobyl situation and those stakes are way too high to by yukking it up, talking about going down memory lane and I really see a lack of integrity. I see a lack of accountability and I am dismayed by this whole entire presentation.

Now, those are my comments and yes, there will be public comments on your - when you put that forward. So those are my comments. My name is Michael Keegan and I'm with No Waste Michigan.

CHAIRMAN BALLINGER: Thank you very - thank you very much. Are there any other folks out there?

MR. KAMPS: Yeah. Can you hear me?

CHAIRMAN BALLINGER: Yes. Who is this?

MR. KAMPS: Yeah. My name is Kevin Kamps with Beyond Nuclear.

CHAIRMAN BALLINGER: Yes?

MR. KAMPS: Yes. Can I go ahead?

CHAIRMAN BALLINGER: Yes.

MR. KAMPS: Okay. Well, I'd just like to say that there is tremendous public concern in southwestern Michigan near Palisades about this issue.

So we have had Mark Kirk come to NRC public meetings. We've had any number of interactions with the NRC in recent years, and going further back in time there was an intervention against the Palisades license extension that was centered on embrittlement risk, and as Mr. Keegan just said the public near Palisades will involve itself as much as possible in the decision making going forward.

CHAIRMAN BALLINGER: Thank you. Anybody else out there? Hearing none, thank you very much, everybody.

Before we quit for the full committee you'll have an hour and a half. So either - you have to sort of consolidate a little bit to make that happen. But since we almost - we have essentially the full committee minus one so - or two. Well, Pete's on the phone.

MEMBER REMPE: Cordini.

CHAIRMAN BALLINGER: Or Cordini.

MEMBER STETKAR: Joyce, who knows?

CHAIRMAN BALLINGER: Anyway, so that's the only comment that I would have. And if there aren't any other - any other questions, thank you very, very much for a really great presentation.

We are adjourned.

(Whereas, the above-entitled matter went off the record at 3:25 p.m.)

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

Advisory Committee on Reactor Safeguards
Materials Subcommittee Meeting

Technical Brief on Regulatory Guidance on the Alternative PTS Rule (10 CFR 50.61a)

Mark Kirk, Sr. Materials Engineer
Gary Stevens, Sr. Materials Engineer
Office of Nuclear Regulatory Research
Component Integrity Branch

Thursday, October 16, 2014
NRC Headquarters
Rockville, MD

Objective

- NRC issued 10 CFR 50.61a in January 2010
- NRC is developing guidance for licensee application of 10 CFR 50.61a
  - Regulatory Guide (RG)
    - Draft Regulatory Guide DG-1299, “Regulatory Guidance on the Alternate Pressurized Thermal Shock Rule”
  - Supporting technical basis NUREG
    - Draft NUREG-2163, “Technical Basis for Regulatory Guidance on the Alternative PTS Rule (10 CFR 50.61a)”
- NRC staff request ACRS review for release of both documents for public comment

Which Plants might use 10 CFR 50.61a?

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- Four plants are currently projected to reach 10 CFR 50.61 limits 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

Outline

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- Background
  - What is 10 CFR 50.61a?
  - Why was 10 CFR 50.61a developed?
- Overview of the Alternate PTS Rule
- Stakeholder Feedback
- Regulatory Guidance:
  - Criteria Relating to the Date of Construction and Design Requirements
  - Criteria Relating to the Evaluation of Plant-Specific Surveillance Data
  - Inservice Inspection (ISI) Data and Nondestructive Examination (NDE) Requirements
  - Criteria Relating to Alternate Limits on Embrittlement
- Estimated Schedule for Reg. Guide Publication

BACKGROUND

What is 10 CFR 50.61a?

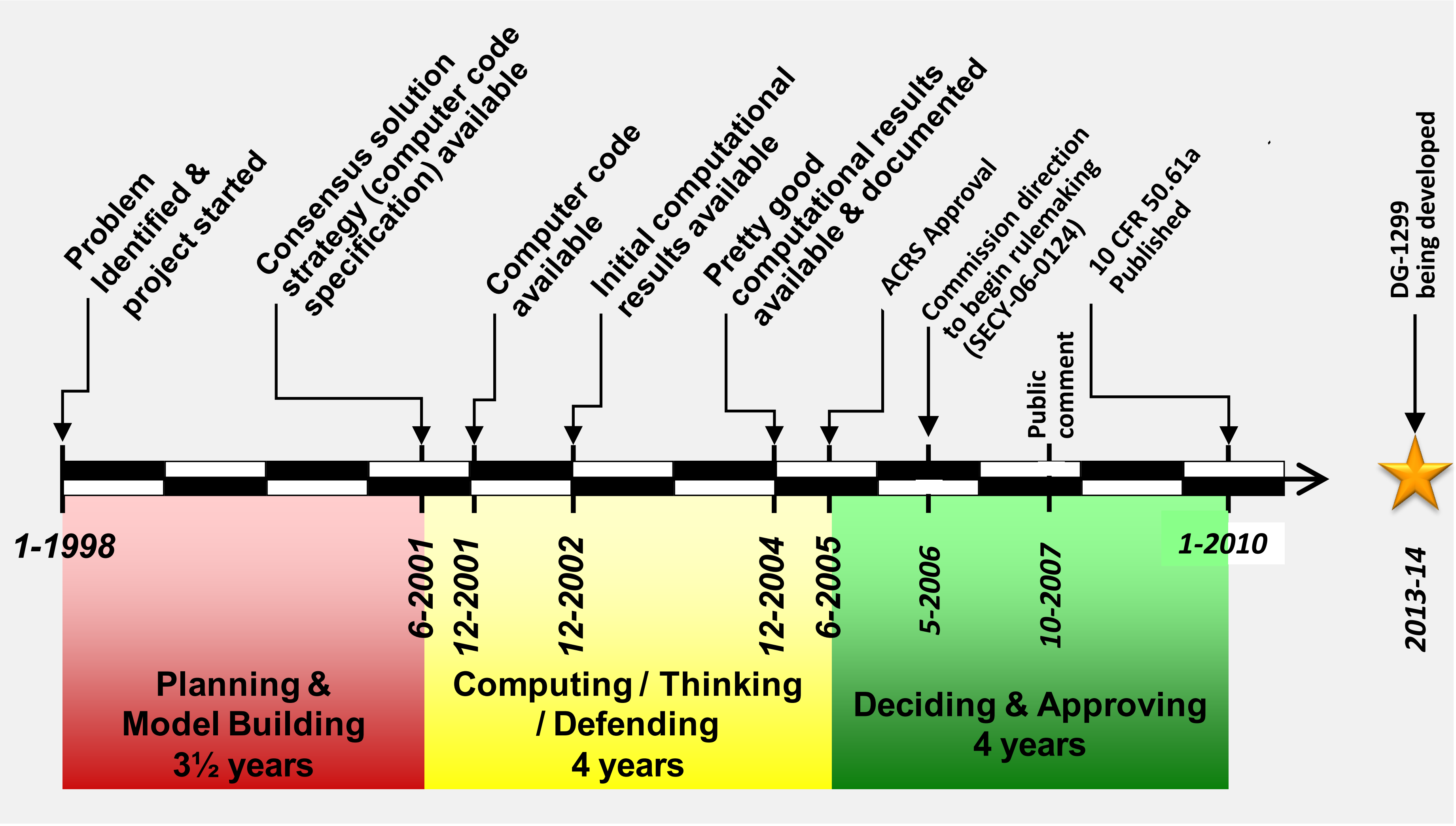
Why was it developed?

(Chapter 1 of NUREG-2163)

The Path to 10 CFR 50.61a

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

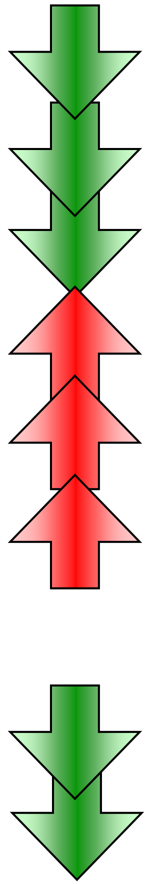
10 CFR 50.61a Timeline



Technical Motivations

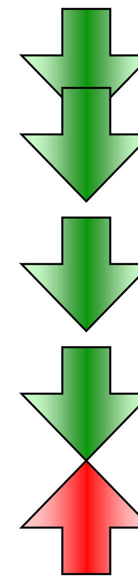
Developments since the 1980s suggested the overall conservatism of the rule

- **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

- **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

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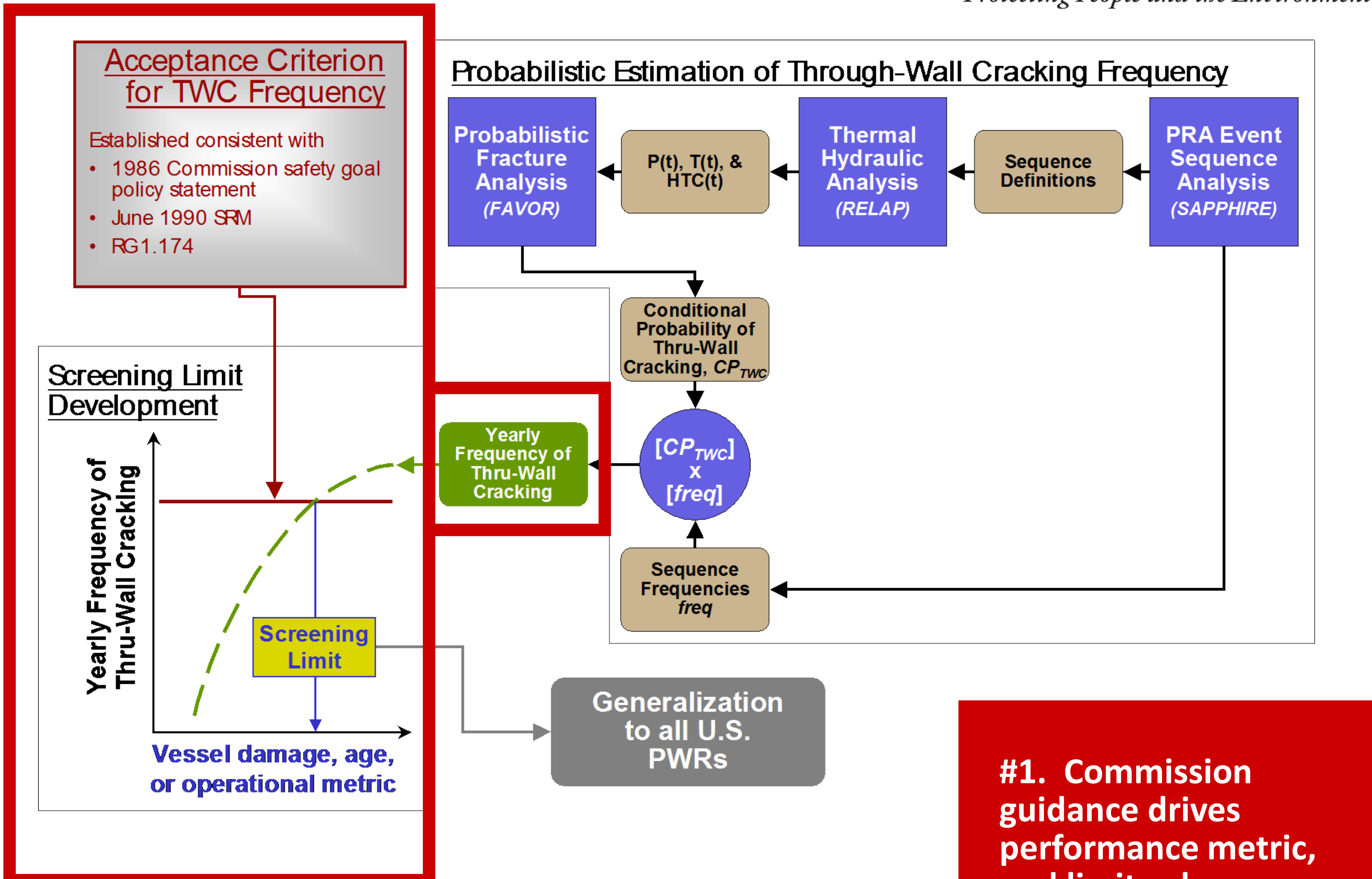
- **Produces unnecessary burden**
  - Technical improvements suggest strongly that current RT_{NDT} limits of 300 °F and 270 °F are more conservative than needed to maintain safety.
- **Does not necessarily increase overall plant safety**
  - Focus on unnecessarily conservative RT_{NDT} limits can divert 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} limits 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 limit value.

PTS Project – Overall Approach

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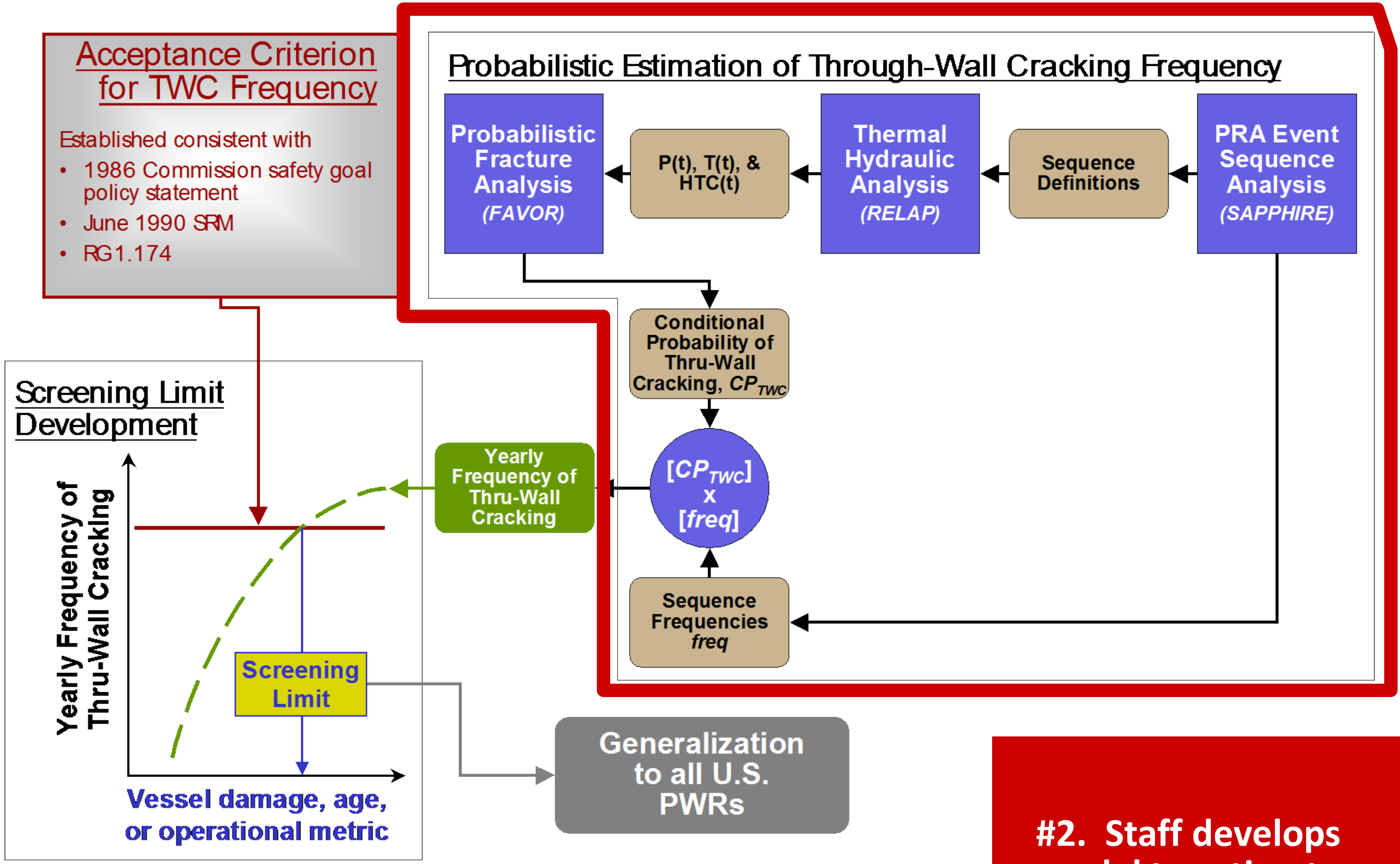
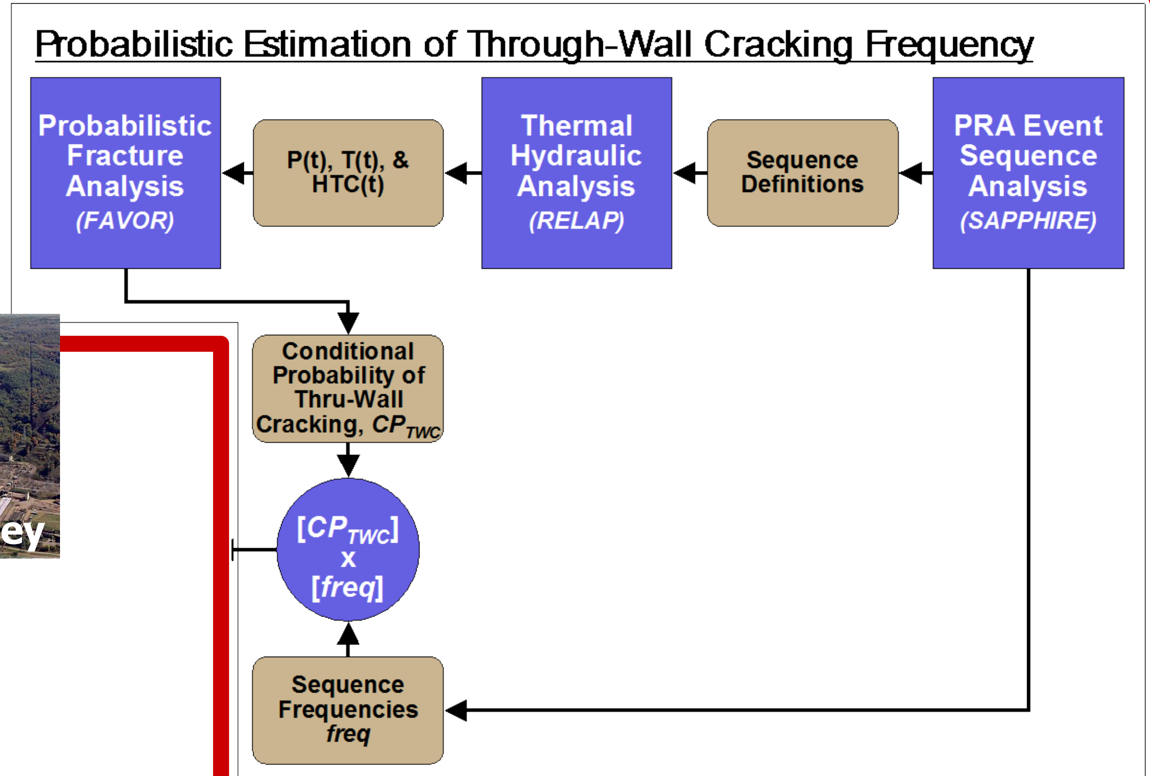
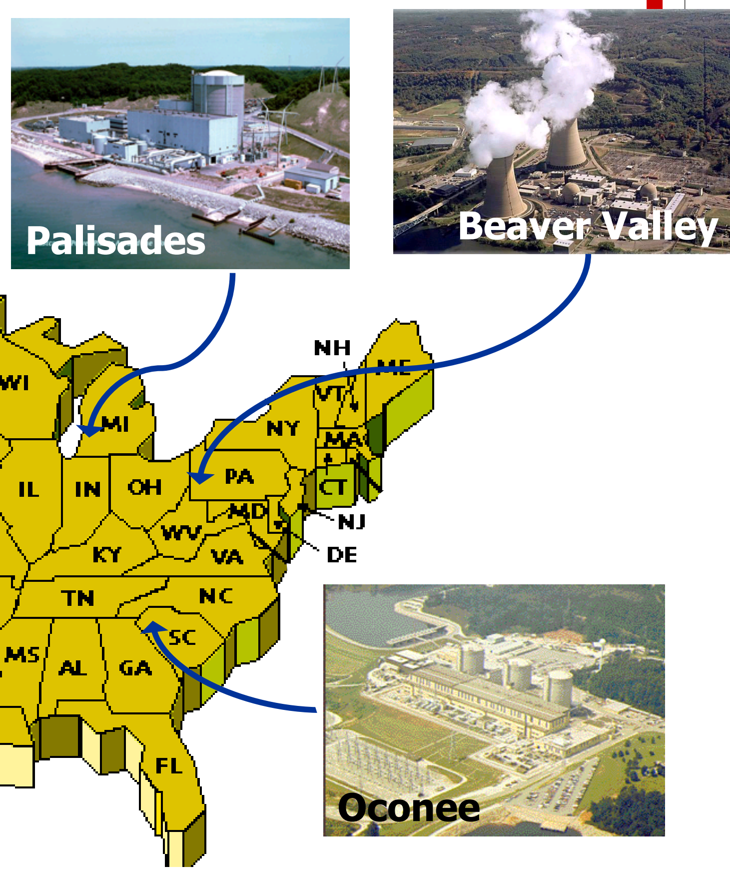


#2. Staff develops model to estimate performance metric.

PTS Project – Overall Approach





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

PTS Project – Overall Approach

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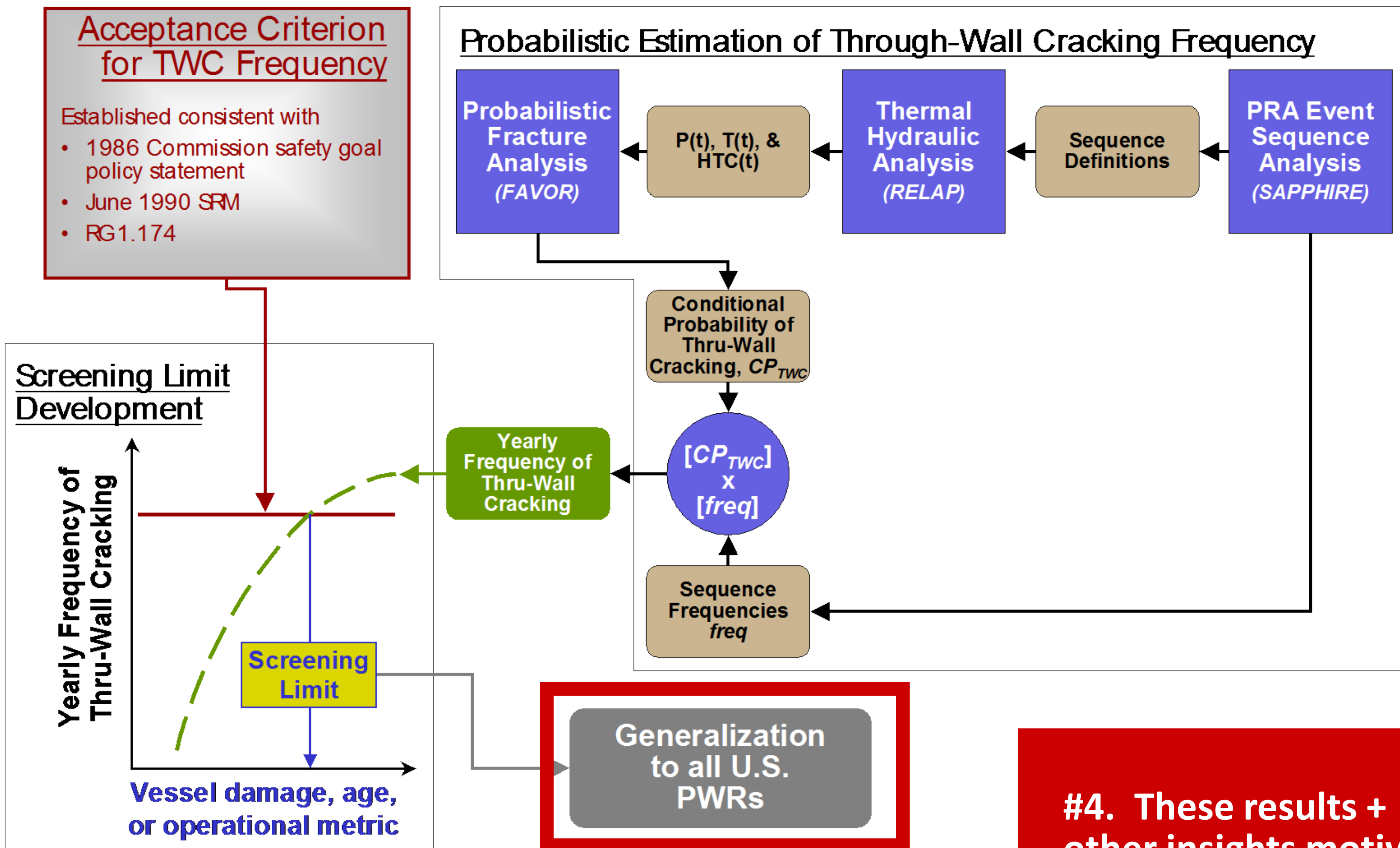

#4. These results + other insights motivate generalization to all plants.

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 limits on embrittlement 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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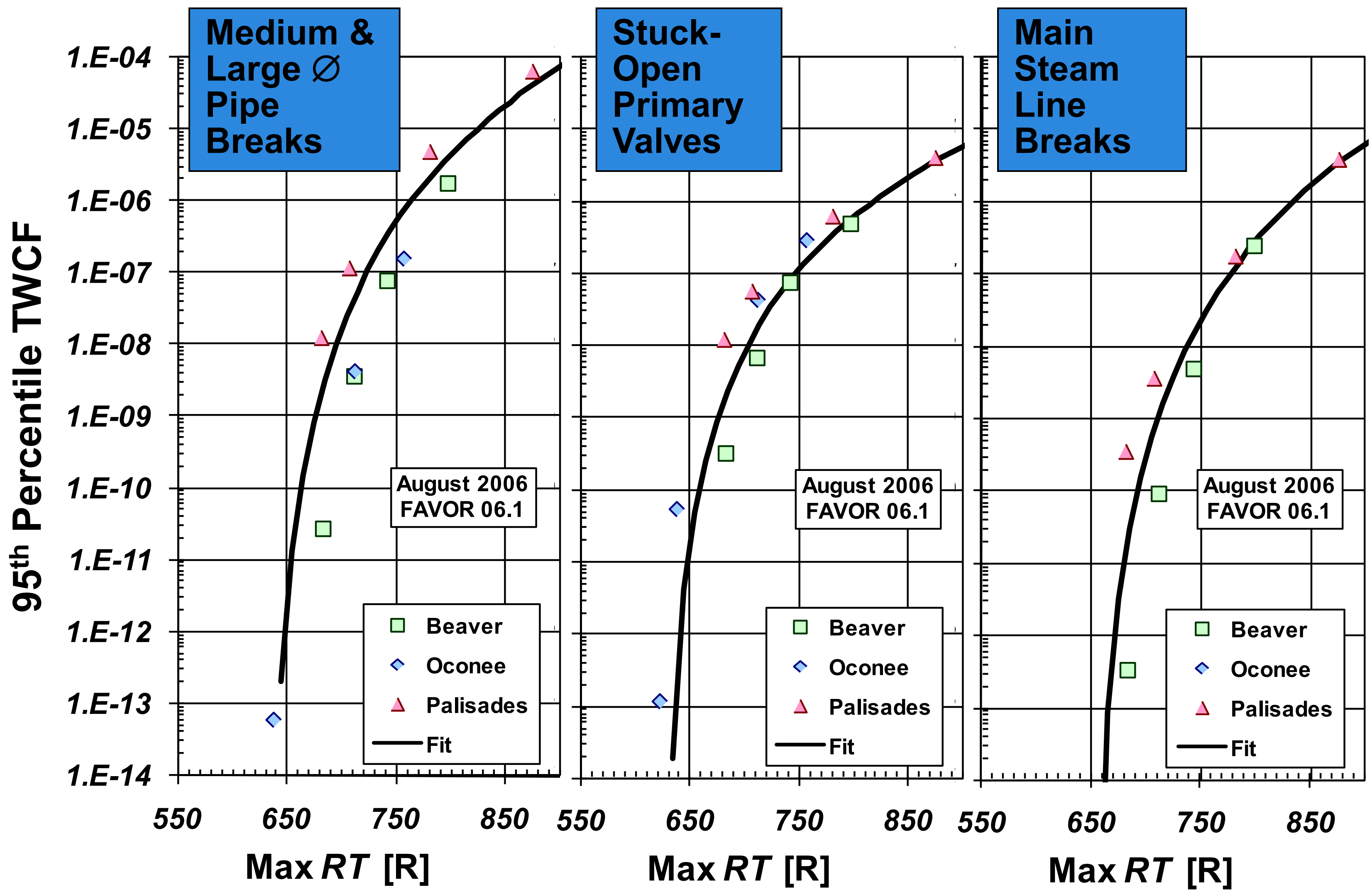

Important Transient Classes

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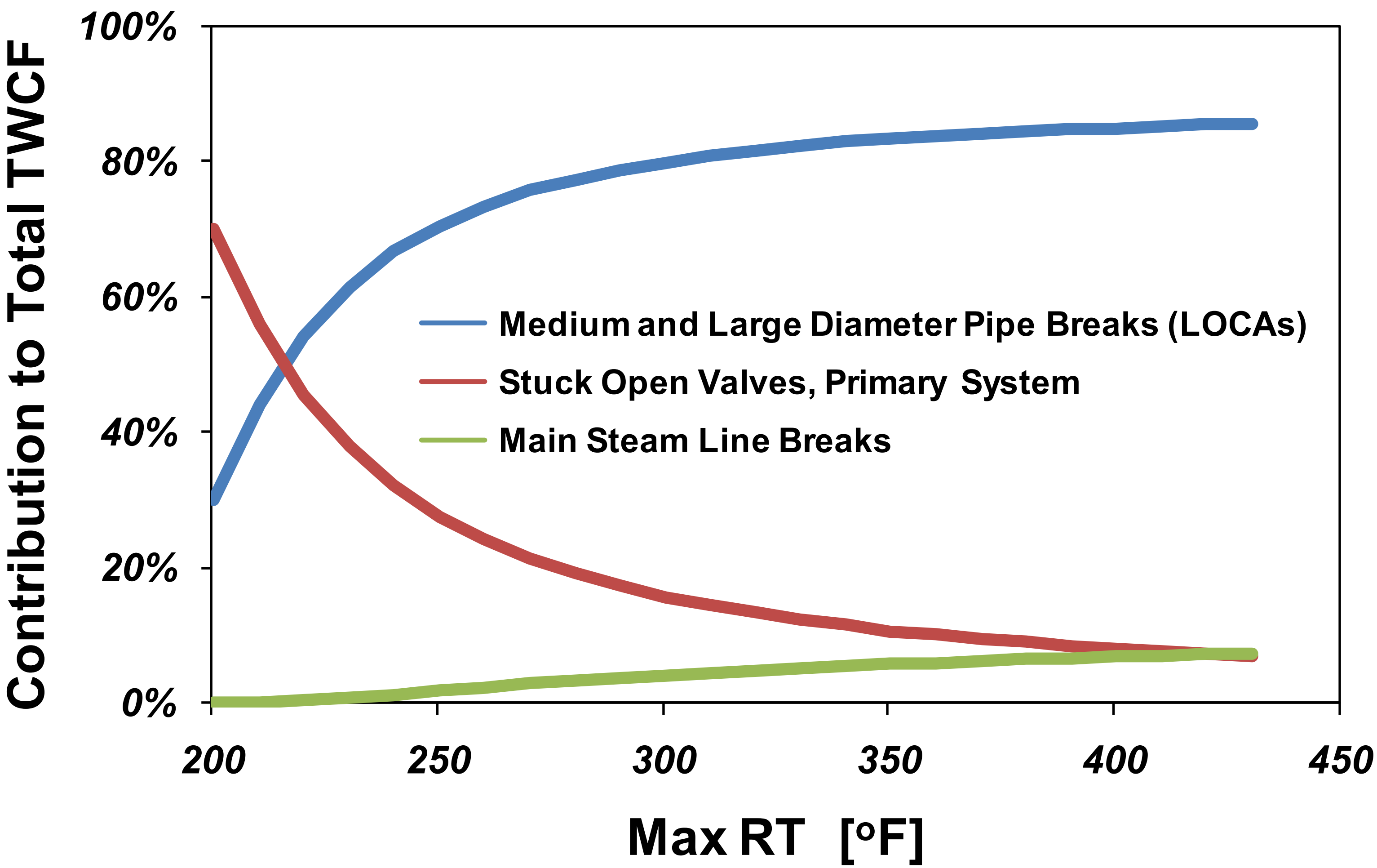

Important Transient Classes

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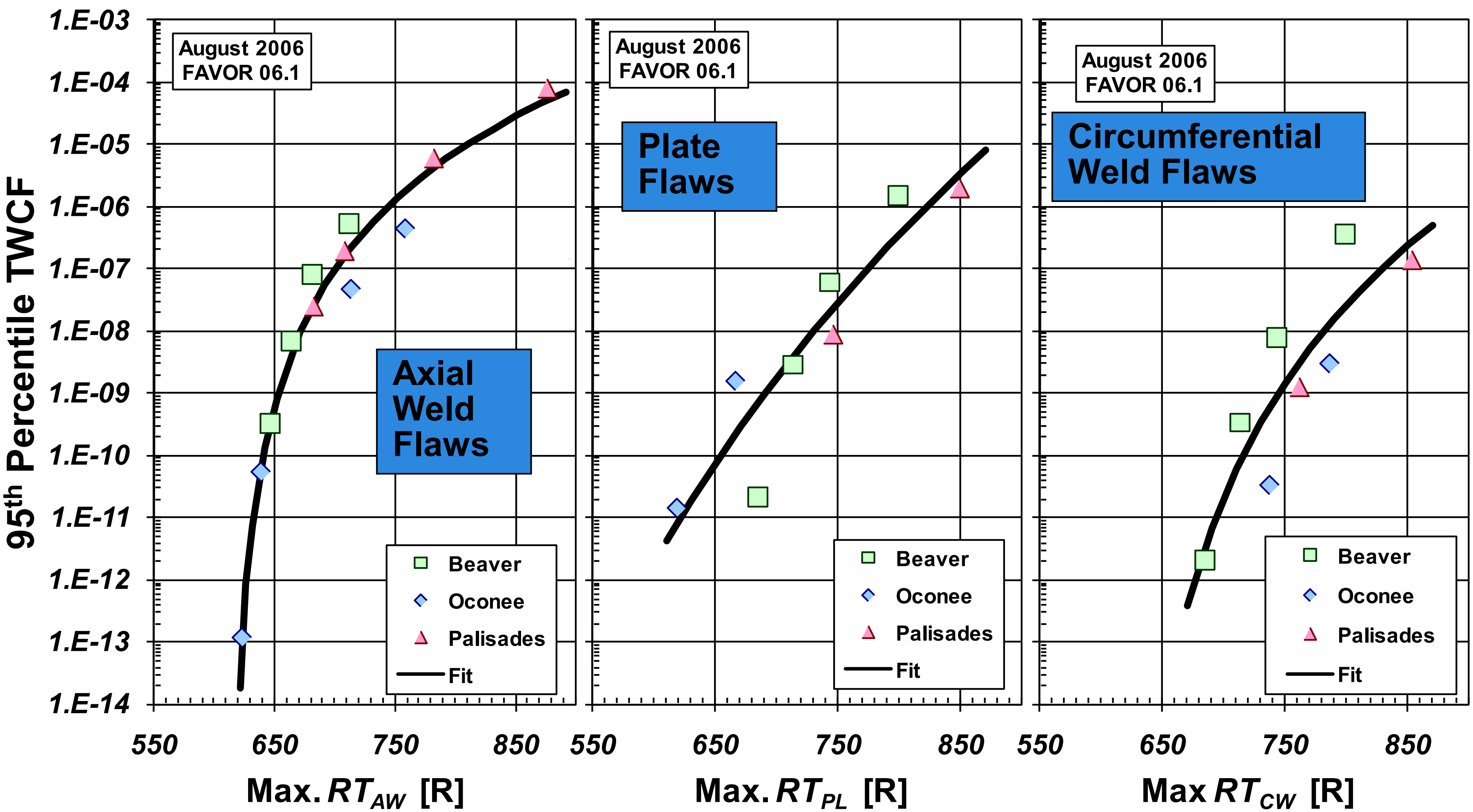
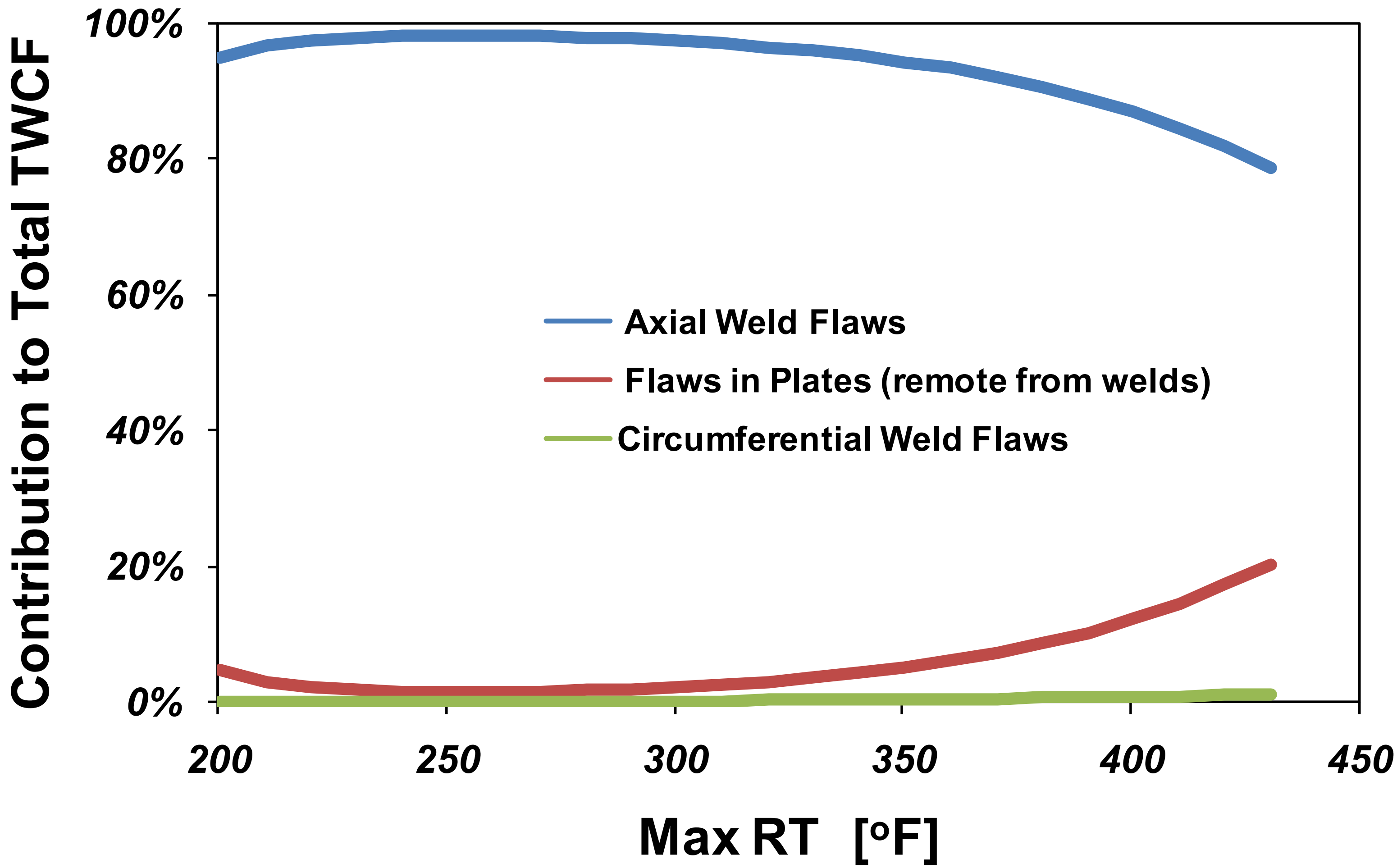
- Primary side faults dominate risk
  - Due to low temperature on primary side (35°F)
- Very severe secondary faults (MSLB) make a minor contribution
  - Primary side temperature cannot fall below 212 °F, so material still tough even at high embrittlement
- All other transient classes produce no significant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

Important Material Features



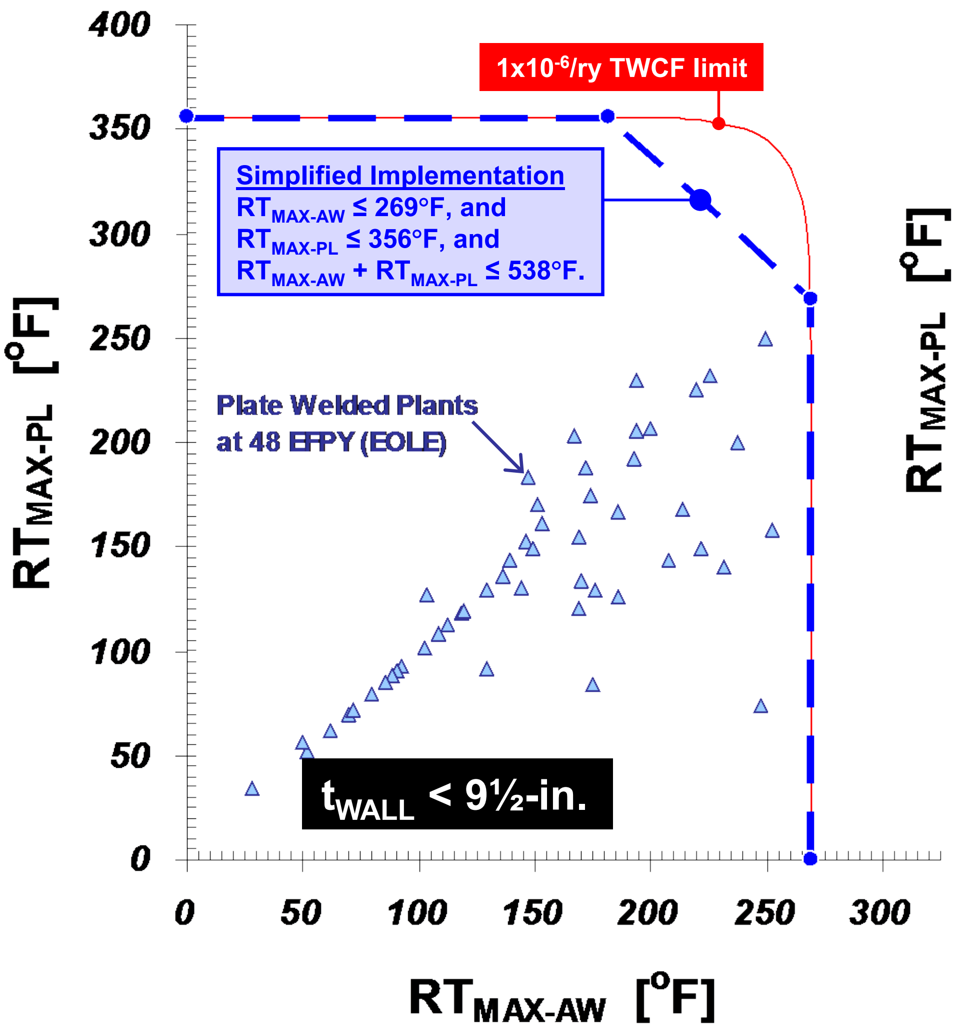
Important Material Features

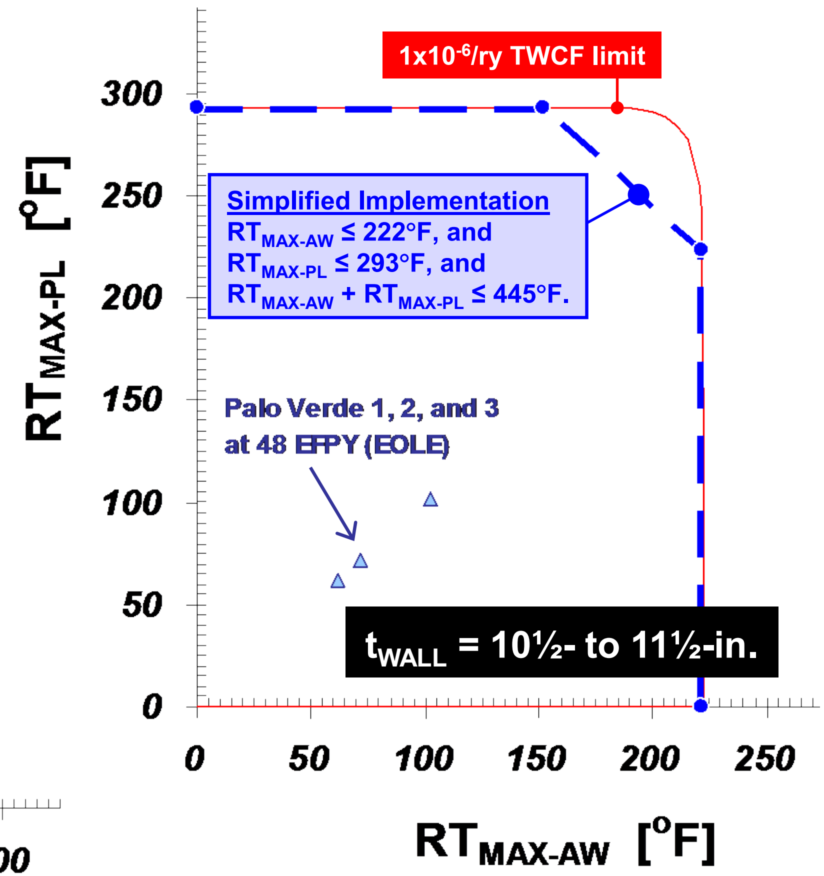


Important Material Features

- **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





OVERVIEW OF THE ALTERNATE PTS RULE

(Chapter 2 of NUREG-2163)

Conditions for Use of 10 CFR 50.61a

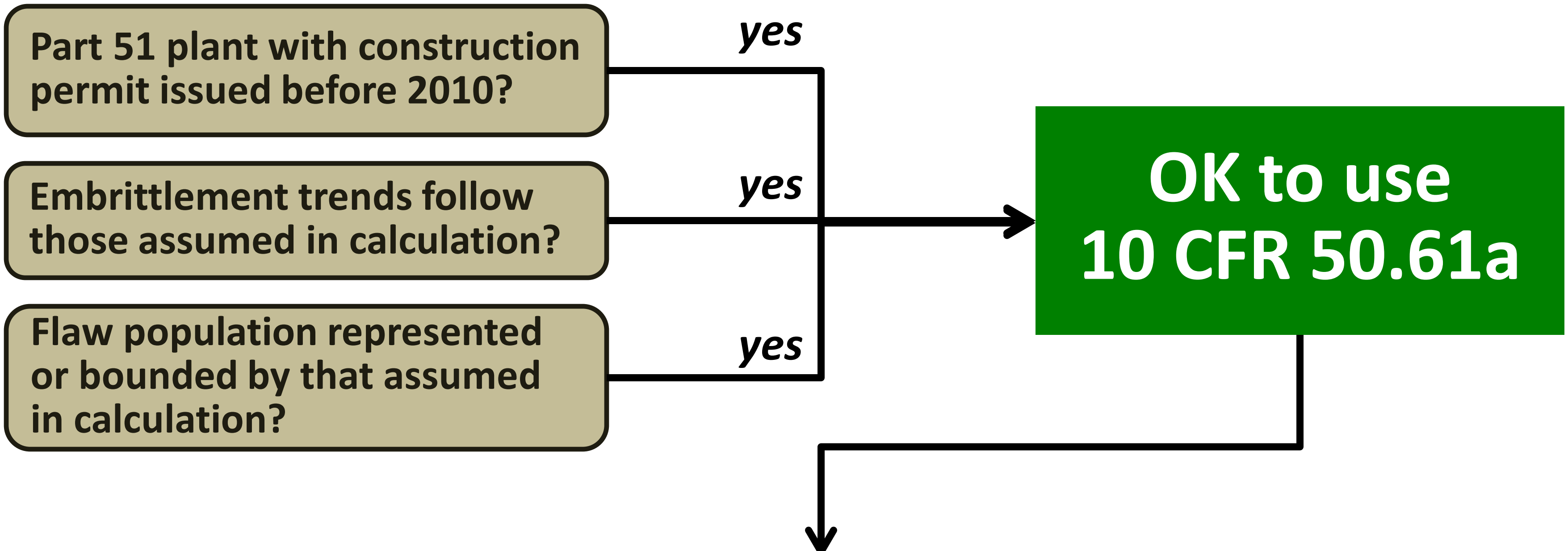


TABLE 1—PTS SCREENING CRITERIA

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

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

	10 CFR 50.61 *REQUIRED*	10 CFR 50.61a *VOLUNTARY*
Reference Temperature Limits	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

STAKEHOLDER FEEDBACK

(Chapter 3 of NUREG-2163)

Stakeholder Feedback

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- The NRC solicited input from interested stakeholders on a 10 CFR 50.61a Reg. Guide
  - 3 public meetings in 2011
- EPRI's Materials Reliability Program (MRP) recommended several technical approaches for NRC to consider
  - Documented in Report No. 1024811, "Materials Reliability Program: Proposed Resolutions to the Analytical Challenges of Alternate PTS Rule (10 CFR 50.61a) Implementation (MRP 334)," January 2012.
  - 7 areas, 15 specific recommendations (Table ES-1 of MRP-334)
  - Intent was to reduce licensee and NRC burden for implementing 10 CFR 50.61a by providing consistent, acceptable levels of safety for cases where compliance evaluations are required

Stakeholder Feedback (cont'd)

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- **EPRI's 7 areas of recommendations:**
  1. Use of sister plant data when performing surveillance data statistical tests.
  2. Adjustment of ΔT_{30} when Mean and Outlier Tests are failed on a plant-specific or heat-specific basis.
  3. Adjustment of ΔT_{30} when the Slope Test is failed.
  4. Criteria that can be used to identify situations in which heat-specific adjustment to generic ΔT_{30} trends need not be considered.
  5. Calculation of through wall cracking frequency (TWCF) and comparison to risk limits if RT_{MAX-X} limits are violated.
  6. Determining whether flaws should be considered as plate or weld flaws when comparing to 10 CFR 50.61a flaw limits.
  7. Qualitative and quantitative solutions when 10 CFR 50.61a flaw limits cannot be satisfied.
- **NRC addressed EPRI's recommendations in Table 3 of NUREG-2163**

REGULATORY GUIDANCE

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

Construction Date

- **Rule & RT limits 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 limits 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

- 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} limits, and
  - That is given by the Rule

Plant-Specific Surveillance Checks

3 Statistical Tests

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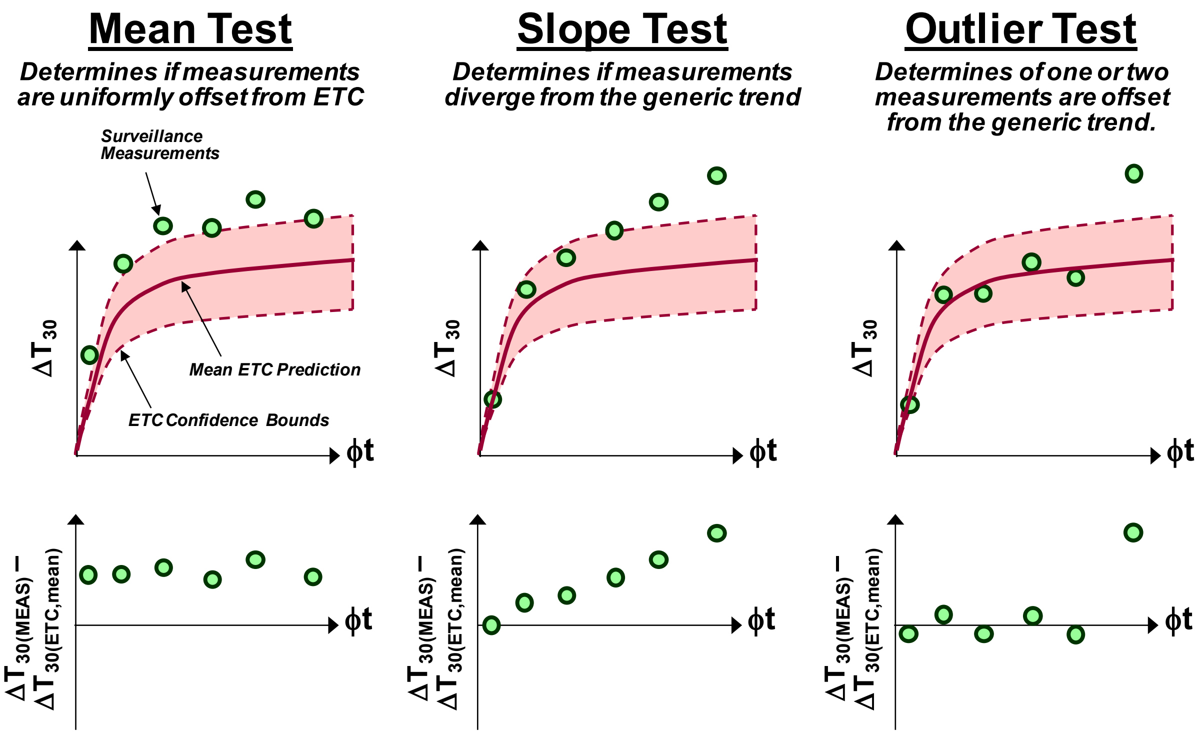
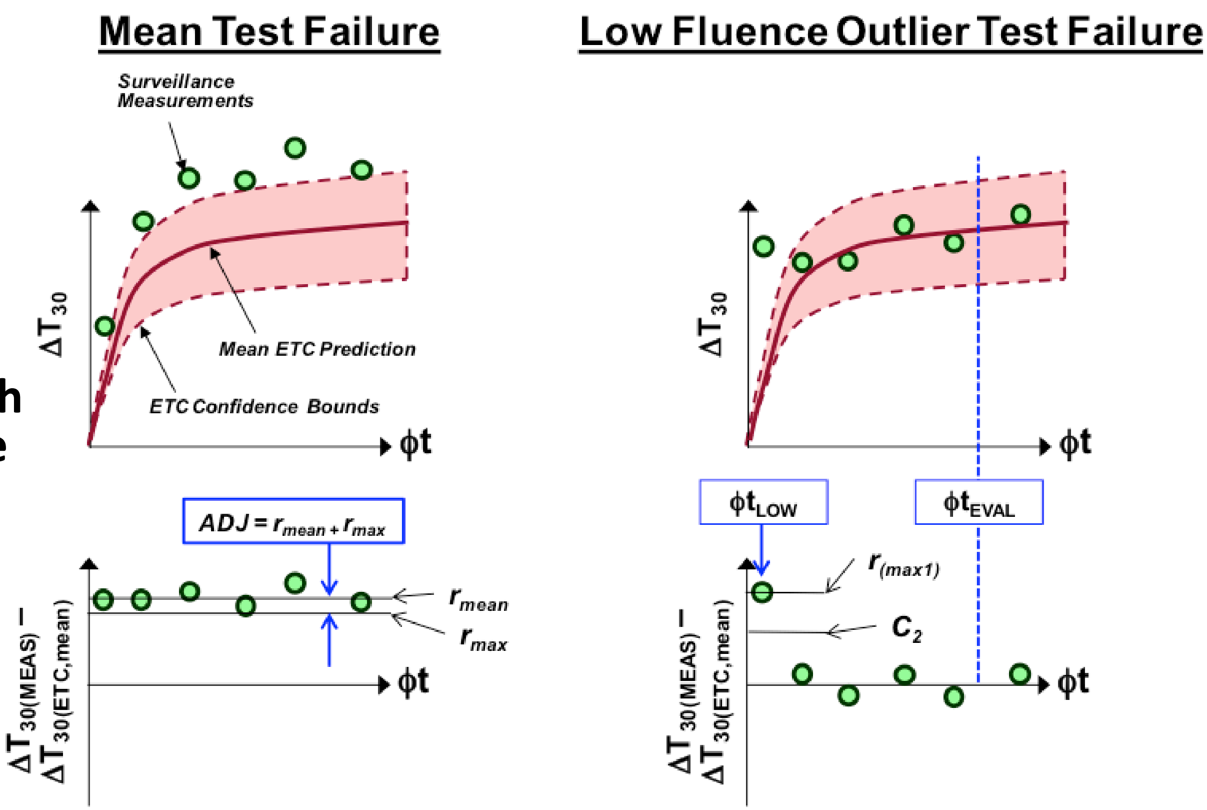
- **Must have 3 or more ΔT_{30} values**
- **Must consider**
  - All beltline plates/welds/forgings for which data is available (not just "limiting" data)
  - Data from "sister plants" if available
- **Only flags under-estimates**
- **3 tests determine different deviations from expected trends**



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



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.] TWE_{MIN}	Through–wall extent, TWE [in.] TWE_{MAX}	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}
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.] TWE_{MIN}	Through-wall extent, TWE [in.] TWE_{MAX}	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.
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

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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

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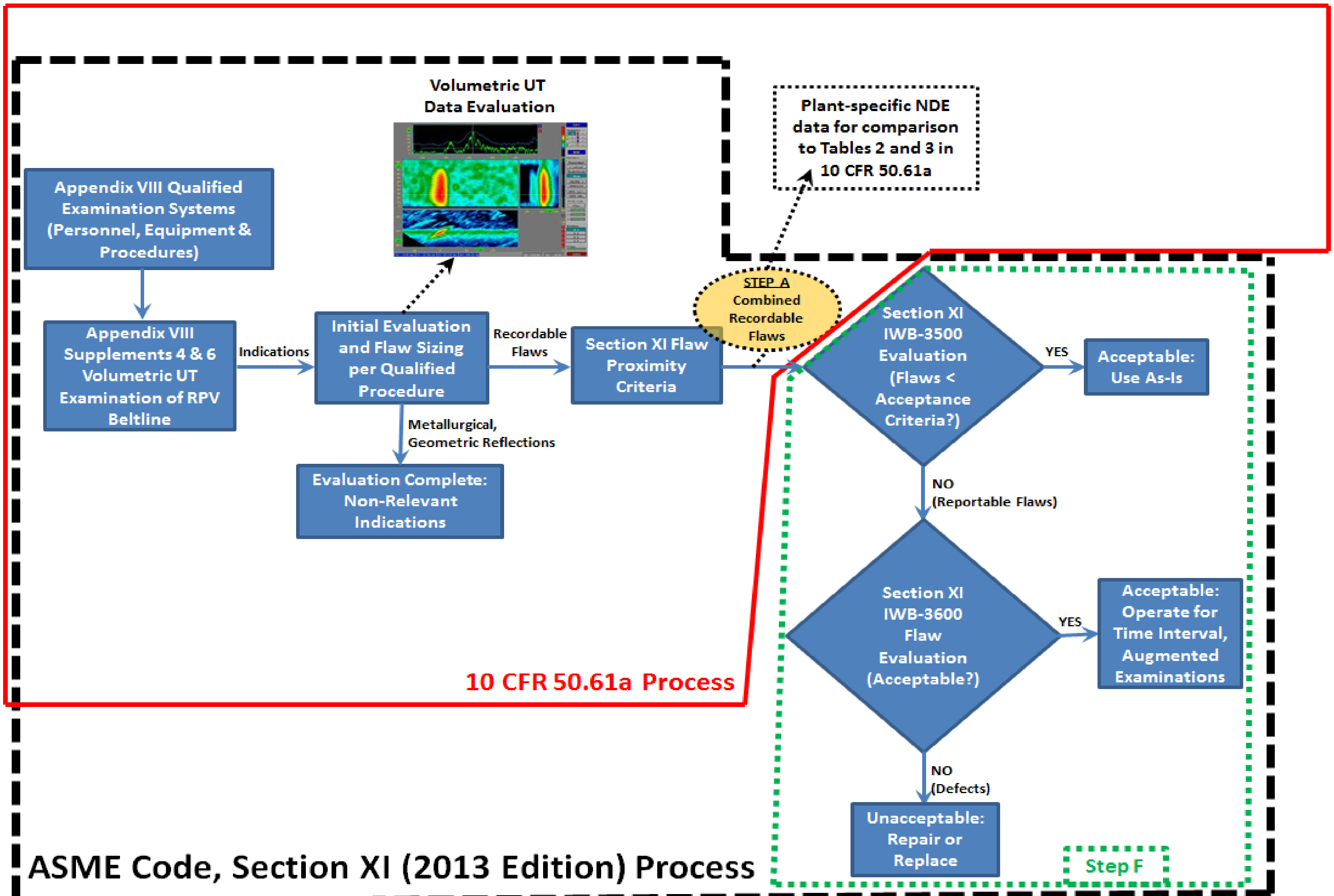
Increasing Risk Significance

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

Results for Comparison to Flaw Tables



NDE Requirements

NDE Results Evaluation Process

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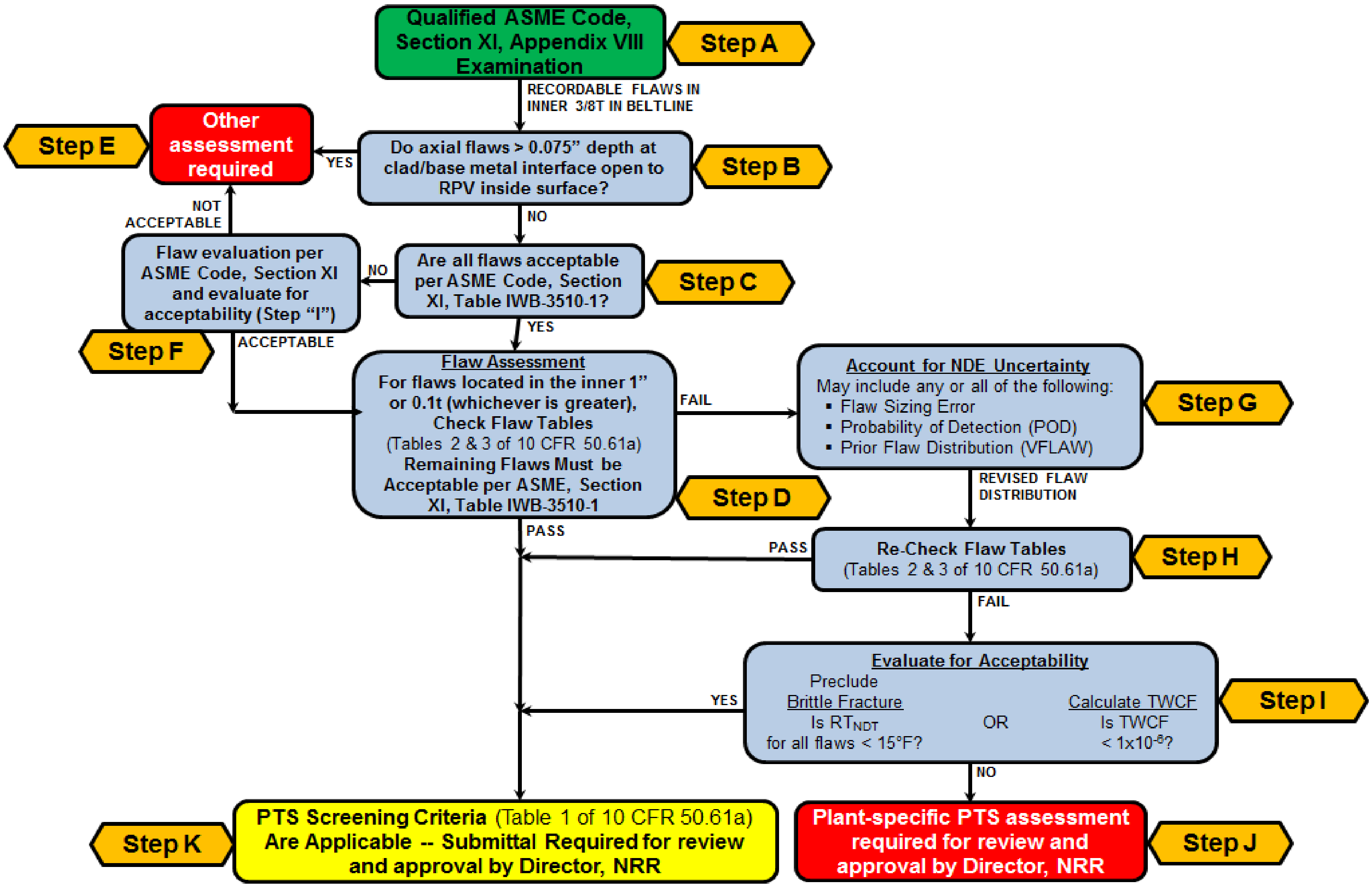
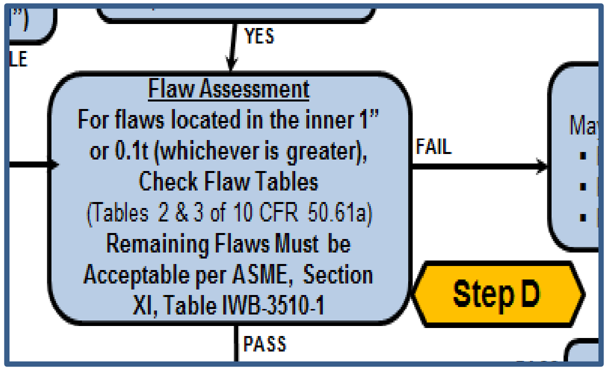


NDE Results Evaluation

Step D – Flaw Assessment



- **Guidance and sample problem provided in Chapter 6.3 of NUREG-2163**
  - **Determine plate and weld flaws** *
  - **Identify flaws in inner 1" or 10% of wall thickness**
    - **Compare to 10 CFR 50.61a flaw tables**
  - **Identify flaws beyond 1" or 10% up to inner 3/8 of wall thickness**
    - **Compare to Table IWB-3510-1**

* **Based on flaw position using design or ISI drawings of weld, with consideration given to heat affected zone.**

NDE Results Evaluation

Step G – NDE Uncertainty

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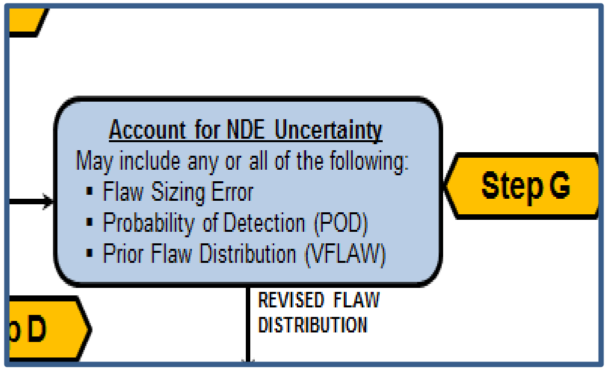
- NDE uncertainty may be accounted for, but is not required
- Guidance for accounting for NDE uncertainty is provided in Chapter 6.4 of NUREG-2163
  - Includes guidance on elements and NDE techniques associated with ASME Code examinations *
- May re-distribute as-detected flaws and allow for acceptable flaw table comparison
  - Flaw sizing errors
    - Oversizing of smaller flaws (+)
  - Probability of Detection (POD)
    - Account for detection uncertainties (-)
  - Prior Flaw Distribution **
    - Adjust the VFLAW distribution used in PTS tech. basis based on plant-specific considerations (+)



* Based on PNNL Report 19666, "Evaluation on the Feasibility of Using Ultrasonic Testing of Reactor Pressure Vessel Welds for Assessing Flaw Density/Distribution per 10 CFR 50.61a, Alternate Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock," June 2014 (ML14162A001).

** Detailed Bayesian statistical methods included in Appendix C of NUREG-2163.

NDE Results Evaluation

Step I – Evaluate for Acceptability

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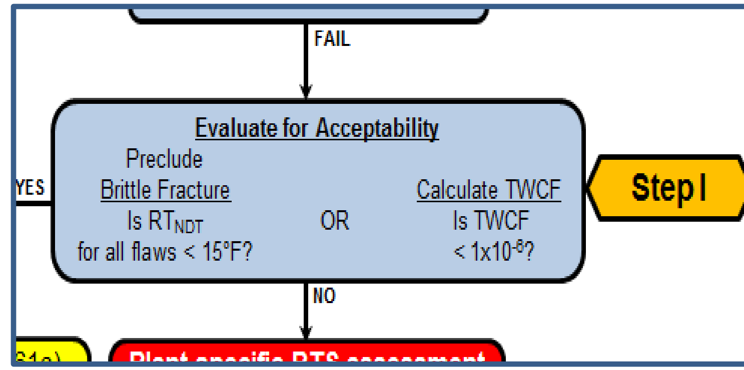
- **If flaw table comparison is unsuccessful, licensees can perform additional evaluation to demonstrate acceptability**
- **Guidance is provided for two options:**
  - **Preclude Brittle Fracture ***
    - **Based on a lower bound PTS transient temperature of 75°F, upper shelf behavior is assured if $RT_{NDT} + 60 \leq 75$°F**
    - **Demonstrate that flaw-specific RT_{NDT} are less than or equal to 15°F**
  - **Calculate TWCF**
    - **Perform plant-specific PFM analysis ****



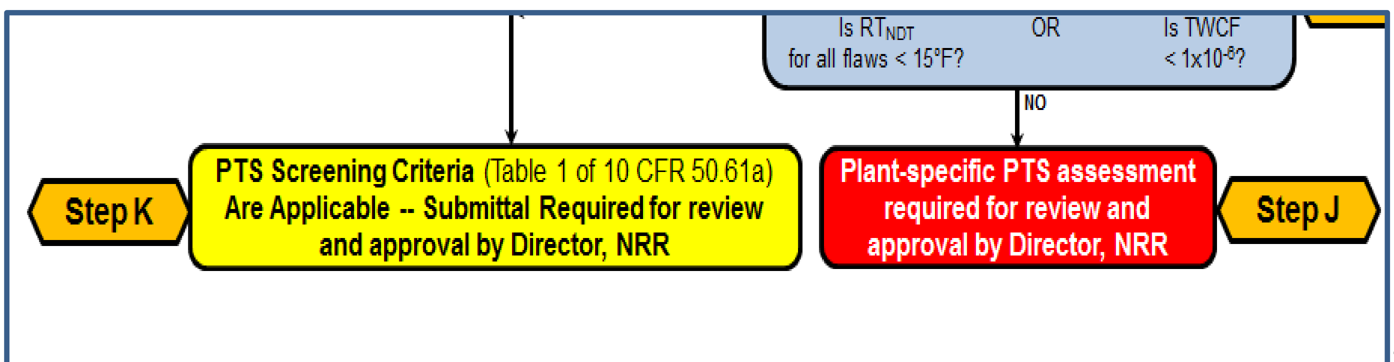
* **Guidance on precluding brittle fracture and a sample problem are provided in Chapter 6.2.1 of NUREG-2163.**

** **Guidance on considerations to include in a plant-specific PFM are provided in Chapter 6.2.2 of NUREG-2163.**

NDE Results Evaluation

Steps J and K - Submittals

- Use of 10 CFR 50.61a PTS screening criteria requires submittal for review and approval by Director, NRR
- For plants that do not satisfy PTS Screening Criteria, plant-specific PTS assessment is required
  - Must be submitted for review and approval by Director, NRR
  - Guidance is not provided for this case
- Subsequent requirements (i.e., after submittal) are defined in paragraph (d) of 10 CFR 50.61a



REGULATORY GUIDANCE

Criteria Relating to Alternate Limits on Embrittlement

(Chapter 7 of NUREG-2163, Position 4 of DG-1299)

Alternate Limits on Embrittlement
Why Are They Needed?

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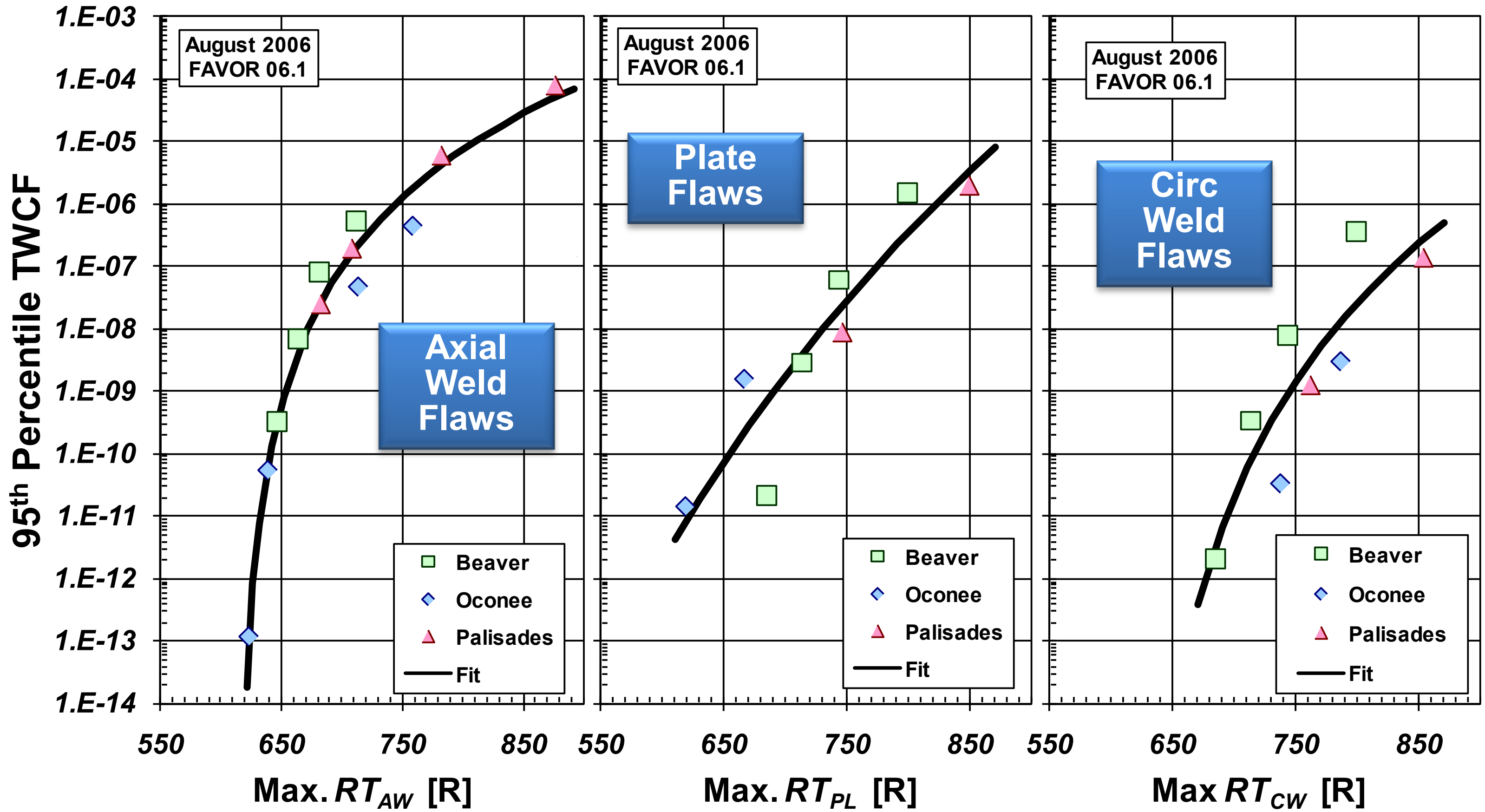
- **Paragraph (c)(3) of 10 CFR 50.61a allows for plant-specific analyses to justify operation if projected RT_{MAX-X} values exceed the PTS screening limits**
- **NRC staff elected to develop one method of acceptable guidance for meeting this provision**
- **Similar feedback was provided by stakeholders**

Alternate Limits on Embrittlement



RT limits based on bounding curve fits to PFM results

Alternate Limits on Embrittlement

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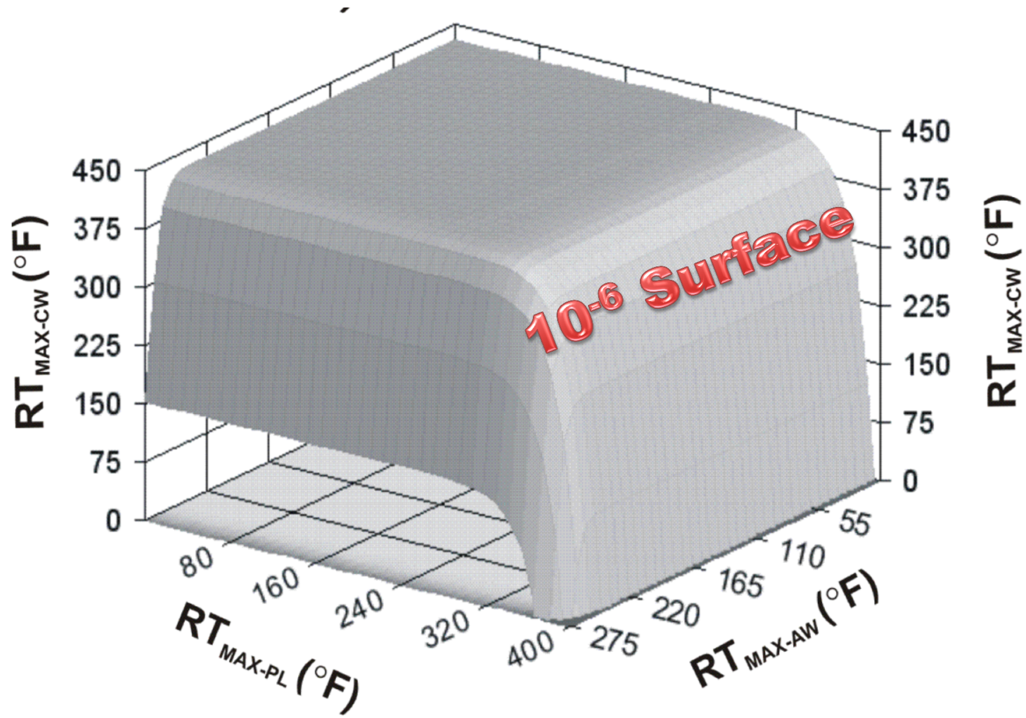
- RT limits table in 10 CFR 50.61a established by inverting this equation
- Simplifications needed to express equation in tabular form
- Licensees can use formula instead of table



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

Axial Weld Flaws — Plate Flaws — Circ Weld Flaws — Forging Flaws

REG. GUIDE PUBLICATION

Estimated Schedule

Schedule

United States Nuclear Regulatory Commission
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- DG-1299
  - Program office review complete; comments addressed
  - ACRS review – minimum 2 weeks *
  - OGC review – minimum 4 weeks *
  - Published for public comment – ~2 weeks
- NUREG-2163
  - Program office review complete; comments addressed
  - ACRS review – minimum 2 weeks *
  - OGC review – minimum 4 weeks *
  - Tech. Pubs. review – ~4 weeks *
  - Published for public comment – ~2 weeks
- Best-Estimate Publication Schedule
  - Public comment (60-day period) – February 2015
  - Publish final documents – Summer 2015

* Schedule depends on comments received.

Questions or Comments?

BACKUP SLIDES #1

Further 10 CFR 50,61a Background Material
(4 slides)

Linkage of PTS Limits on TWCF to CDF & LERF Policy Decisions

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51 FR 28044, *Safety Goal Policy Statement (1986)*

QHOs < 0.1% of the total public risk (prompt & latent)

SECY-00-0077, *Modifications to Safety Goal Policy Statement*

CDF < 1×10^{-4}/ry

CDF & QHO limits for generic decisions

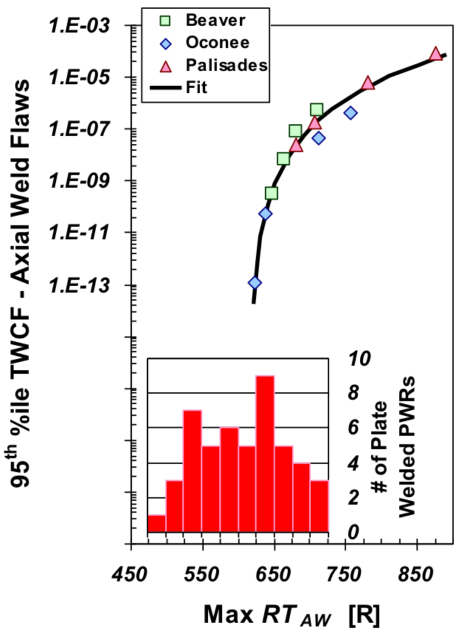
Regulatory Guide 1.174

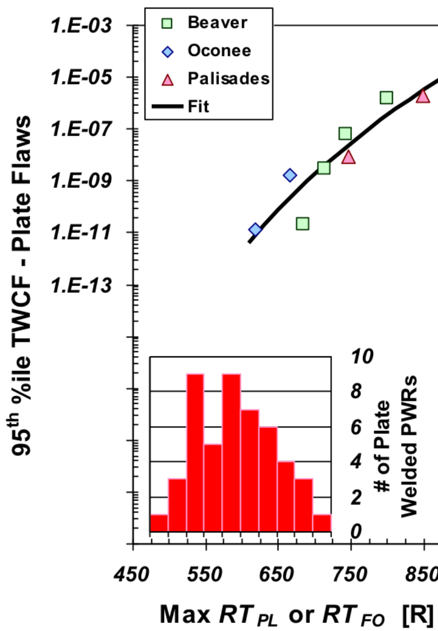
	Mean	Δ-Mean
CDF	10^{-4}/ry	10^{-5}/ry
LERF	10^{-5}/ry	10^{-6}/ry

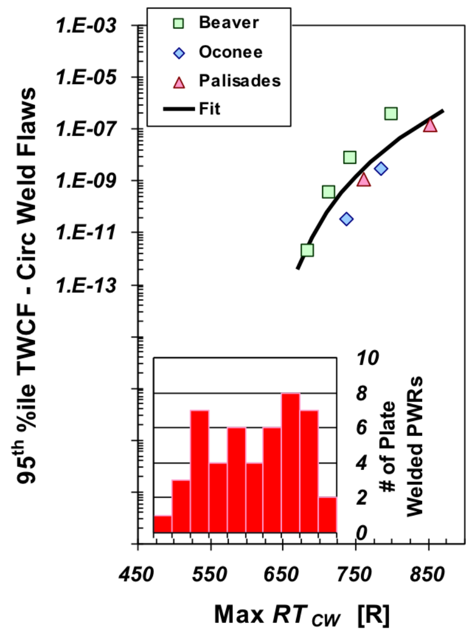
10 CFR 50.61a

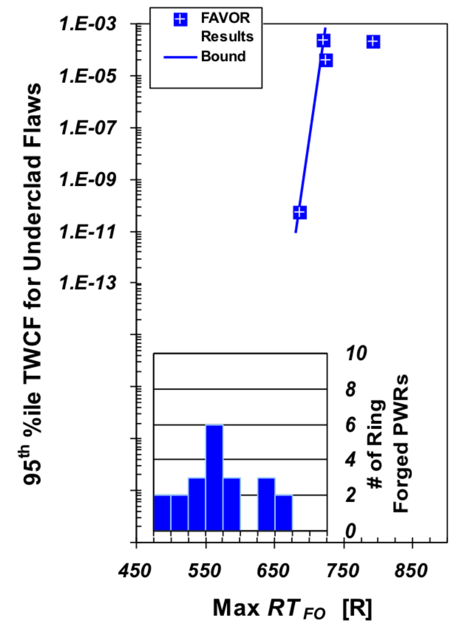
Voluntary Alternative Pressurized Thermal Shock Rule

- Accident sequence progression study shows that through-wall cracking rarely leads to LERF
- Conservatively assumes equivalence of LERF and the yearly through-wall cracking frequency (TWCF) of the reactor pressure vessel
- **Tolerable limit on TWCF established as 10^{-6}/ry**

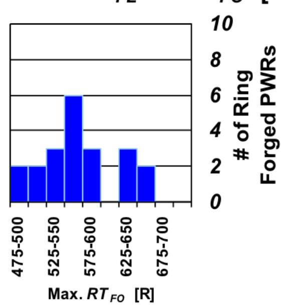


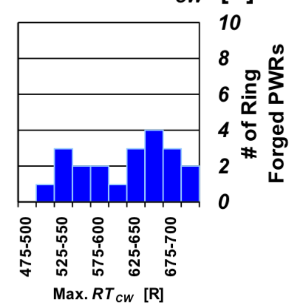






Histograms depict current estimates of *RT* values at *EOLE* (48 EFPY)





Overall Approach

- **A risk-informed / probabilistic approach was taken to develop the technical basis for rule revision**
  - **Links to Commission policy guidance**
  - **Provides a systematic framework to account for / address uncertainties across a wide range of technical disciplines**
  - **Recognizes that conventional / deterministic thinking about problems involving complex systems may lead to the (erroneous) conclusion that operations cannot continue**

Keep in Mind …

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- Saying that uncertainties are ***addressed*** does not mean that uncertainties are ***modeled*** (i.e. mathematically carried through the numerical models used to estimate the performance metric)
- There are ways to address uncertainties without numerically propagating them
  - Model them conservatively
  - Show they can be ignored because
    - Because they have no effect on the predicted values of the performance metric
    - Because they are small
      - Relative to other uncertainties in the model
      - Absolutely
- Bottom line: Important uncertainties are modeled, unimportant uncertainties are not
  - We spent ***MUCH*** time debating what is "important" (about 5 years)

BACKUP SLIDES #2

Bayesian Statistical Methods

(4 slides)

Bayesian Statistical Methods (1/4)

Overview of the Approach and Data

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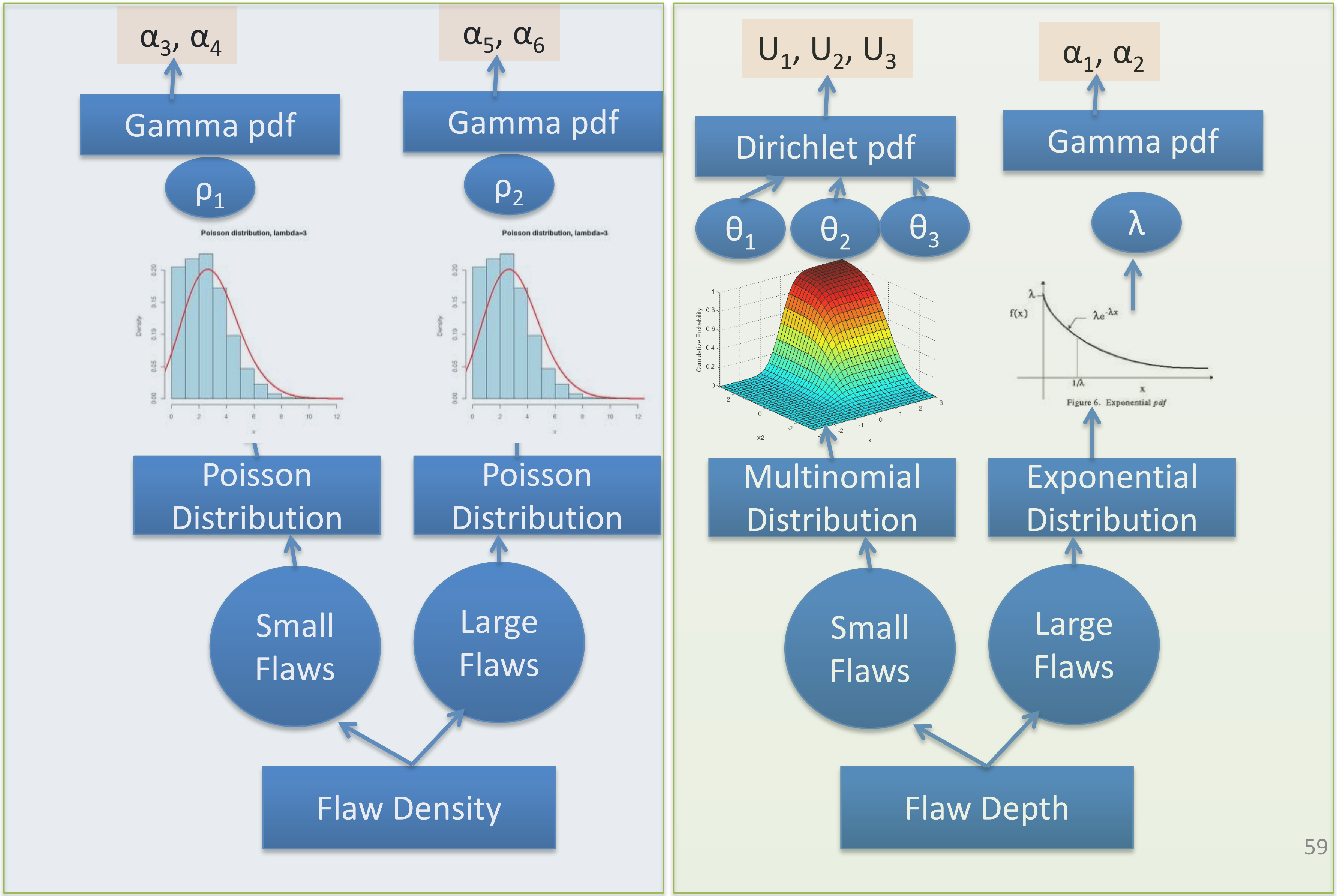
- Used Bayesian updating for flaw depth and flaw density
- VFLAW assumes exponential distribution for large flaw depth (i.e., when flaw depth > weld bead thickness) and multinomial distribution for small flaws
- VFLAW uses Poisson distribution for flaw density
- Parameters of exponential distribution and Poisson distribution are modeled by Gamma distributions
- Parameters of the multinomial distribution are modeled by the Dirichlet distribution
- Application of the Bayesian analysis to Beaver Valley

Bayesian Statistical Methods (2/4)

Hierarchy of VFLAW Distributions



Bayesian Statistical Methods (3/4)

Overall Updating Procedure

Prior Knowledge <u>VFLAW</u> flaw distribution (depth & density)

UT Data considered as <u>evidence</u> of flaw distribution

→

<u>Real</u> flaw distributions (depth & density)

Let Θ = Vector of parameters of flaw depth and density distributions

Updated or Posterior estimates of Θ

Likelihood of observed UT data

Prior estimates of θ from VFLAW

$$\pi_1(\underline{\theta} \mid \text{Observed Data}) = \frac{L(\text{Observed Data}|\underline{\theta})\,\pi_0(\underline{\theta})}{p(\text{Observed Data})}$$

Probability of observed data regardless of Θ= integral of numerator over θ

Bayesian Statistical Methods (4/4)

Bayesian Computational Procedure