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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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2 NUCLEAR REGULATORY COMMISSION

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4 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

5 (ACRS)

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7 METALLURGY & REACTOR FUELS SUBCOMMITTEE

8 + + + + +

9 THURSDAY

10 AUGUST 22, 2019

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12 ROCKVILLE, MARYLAND

13 + + + + +

14 The Subcommittee met at the Nuclear
15 Regulatory Commission, Two White Flint North, Room
16 T2B10, 11545 Rockville Pike, at 1:00 p.m., Ronald G.
17 Ballinger, Chairman, presiding.

18
19 COMMITTEE MEMBERS:

20 RONALD G. BALLINGER, Chair

21 WALTER L. KIRCHNER, Member

22 JOSE MARCH-LEUBA, Member

23 DAVID PETTI, Member*

24 JOY L. REMPE, Member

25 PETER RICCARDELLA, Member

DESIGNATED FEDERAL OFFICIAL:

CHRISTOPHER BROWN

ALSO PRESENT:

DAVE ALLEY, NRR

BRIAN HALL, Westinghouse

TIM HARDIN, EPRI

RAJ IYENGAR, RES

MARK KIRK, CRIEPI

LOUISE LUND, NRR

MATTHEW MITCHELL, NRO

RANDY NANSTAD, Oak Ridge National Laboratory

NATHAN PALM, EPRI

JEFF POEHLER, RES

PATRICK REYNAUD, RES

ROBERT TREGONING, RES

DAN WIDREVITZ, RES

*Present via telephone

C-O-N-T-E-N-T-S

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P R O C E E D I N G S

1:01 p.m.

CHAIR BALLINGER: This meeting will now come to order. Sort of. This is a meeting of the Advisory Committee on Reactor Safeguards Metallurgy and Reactor Fuel Subcommittee. I'm Ron Ballinger, Chairman of the Subcommittee.

Members in attendance are Walt Kirchner, Pete Riccardella, Joy Rempe, Jose March-Leuba, and on the phone, Dave Petti. Chris Brown is here somewhere, is the designated federal official for this meeting.

The purpose of today's meeting is for the Subcommittee to receive a briefing on the staff's development of a white paper on the adequacy of Revision 2 of Regulatory Guide 1.99. Today we have members of the NRC staff and EPRI, I think, and others to brief the Subcommittee.

The ACRS was established by statute and is governed by the Federal Advisory Committee Act, FACA. That means that the Committee can only speak through its published letter reports and we hold meetings to gather information to support our deliberations.

Interested parties who wish to provide comments can contact our office requesting time. That said, we set aside 10 minutes for comments from

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1 members of the public attending or listening to our
2 meetings. Written comments are also welcome.

3 The meeting agenda for today's meeting was
4 published on the NRC's public meeting notice website,
5 as well as the ACRS meeting website. On the agenda
6 for this meeting and on the ACRS meeting website are
7 instructions as to how the public may participate. No
8 requests for making a statement to the Committee has
9 been received from the public.

10 A transcript of the meeting is being kept
11 and will be made available on our website. Therefore,
12 we request that participants in this meeting use the
13 microphones located throughout the meeting room when
14 addressing the Subcommittee, and in the front, make
15 sure the little green light is on when you're talking.

16 Participants should first identify
17 themselves and speak with sufficient clarity and
18 volume so they can be readily heard. We have a bridge
19 line established for the public to listen to the
20 meeting. To minimize disturbances, the public line
21 will be kept in a listen mode only.

22 To avoid disturbance, we request that
23 attendees put their electronic devices, cell phones
24 and other kinds of things in a noise free mode or off.

25 We will now proceed with the meeting and

1 I'll ask Ms. Louise, yes, Louise Lund, Director of the
2 Division of Licensing projects, NRR, to make
3 introductory remarks before we begin today's
4 presentations. You've got to make sure the light's on
5 as well.

6 MS. LUND: We were just looking at that,
7 but it sounds like the microphone is on to me.

8 CHAIR BALLINGER: Yeah, it is.

9 MS. LUND: Okay, sounds good. All right,
10 so thank you, and my name is Louise Lund, and as of
11 this week, I just started as the Division Director for
12 the Division of Engineering in the Office of Research.

13 So, that said, we're here today to talk
14 about the Regulatory Guide 1.99 Rev 2, radiation
15 embrittlement of reactor vessel materials, which is
16 used by licensees in the operating fleet to determine
17 the change in reactor vessel properties due to
18 irradiation.

19 As such, the guidance of the Reg Guide is
20 used to determine the adjusted reference temperature,
21 which is used to determine the fracture toughness, a
22 key input to pressure temperature limits.

23 The Reg Guide also provides guidance for
24 assessing the change in upper shelf energy, which is
25 related to ductal fracture resistance. Both of these

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1 properties are needed to show compliance with 10 CFR
2 50, Appendix G.

3 So it should be noted that the current Reg
4 Guide dates from 1988. Since that time, a large
5 amount of test data on irradiated reactor vessel
6 materials has been obtained from tests of surveillance
7 materials.

8 So, with licensees planning to operate
9 plants out to 60 to 80 years, it is important that
10 guidance for assessing embrittlement is adequate for
11 the neutron fluence levels that are projected for
12 these plants.

13 New plants will use reactor vessel
14 materials with different chemistries than are typical
15 of the operating fleet. Therefore, the NRC staff
16 performed an assessment of the adequacy of Reg Guide
17 1.99, Revision 2 based on these considerations.

18 So today's presentation summarizes a
19 multiyear effort to thoroughly assess Reg Guide 1.99
20 through a modern data driven approach.

21 At this time, the assessment does not
22 address licensing basis or policy decisions, and
23 discussion of next steps and regulatory implications
24 has not been part of this assessment and will be the
25 subject of further discussion, and the staff and also

1 the management, so that's not, that will not be part
2 of the presentation today as well.

3 So we do have the staff up here at the
4 table, and of course I have Raj, the branch chief,
5 with me, and also there is Dan Widrevitz and also Matt
6 Mitchell, who will be representing the staff, and here
7 is Dave Alley as well, so that concludes my opening
8 remarks.

9 MEMBER REMPE: I had a question that I
10 might as well bring up to you even though I know you
11 just started this position, but the fact of this Reg
12 Guide, I thought they were supposed to be revised
13 every 10 years. Is this a problem that should be
14 emphasized?

15 MS. LUND: And that's a very good point,
16 okay. It's not so much that they get revised every 10
17 years in as much as they are looked at for whether
18 revisions are necessary, and obviously, you know,
19 depending on how extensive the revisions would be,
20 that would dictate the schedule.

21 MEMBER REMPE: But this one should have
22 been looked at every 10 years and it should have been
23 acknowledged, and I thought some of the information I
24 read said it was recognized it needed to be updated,
25 but this is --

1 MR. IYENGAR: Yeah, it was --

2 MEMBER REMPE: -- quite a bit of time.

3 MR. IYENGAR: So we do a periodic review
4 of all important Reg Guides, and this Reg Guide, a
5 periodic review was done in 2014 if I am right. At
6 the time, the staff concluded that at this moment,
7 this Reg Guide is adequate at this moment, and then
8 further we considered the revision given the next
9 cycle, which is what we are doing right now.

10 MS. LUND: And I think also at the end of
11 the presentation, they're also going to explain the
12 time frame in which we expect to need additional
13 information or, you know, when this could be
14 necessary, so we'll discuss that as well.

15 MEMBER REMPE: Thank you.

16 MR. WIDREVITZ: All right, well, good
17 afternoon, everyone. My name is Dan Widrevitz. I'm
18 a member of the Office of New Reactors and I was, Raj
19 gave me the opportunity to come over and spend some
20 time in research to help them write the assessment.

21 Obviously there were many hands in this
22 assessment. It's not the work of one person. Many of
23 those hands are in this room right now, so I'd like to
24 thank everyone who helped me get us here today, so
25 with that, I'd like to begin.

Sort of reiterating on Louise's introduction, I really want to -- we have to emphasize this is the result of a multiyear effort attempting to assess the Reg Guide through a data driven approach.

The assessment does not, very specifically, we were careful, it does not address licensing basis or policy decisions. This is strictly a technological assessment.

In a sense, you could say that the question we were looking into is how accurate is the Reg Guide, not necessarily what the significance of any potential inaccuracies or accuracies is. Those are a little bit separated, so this is more of sort of a research technology context, a little bit less of a program office policy context.

In terms of discussions of next steps and regulatory implications, it's just not part of this assessment, and we really, we don't have much to share during this meeting today on that. That's really an ongoing effort that's very early.

So to give you an idea of what we're going through today, coincidentally it looks exactly like how the assessment is structured. We're going to go through a little bit of background, talk about the RTndt results, the delta upper shelf energy results,

1 credibility criteria, plant specific data results,
2 attenuation, common additions, and we'll wrap up with
3 some conclusions and a very, very brief statement
4 about next steps, essentially going through the
5 contents of the Reg Guide and what our findings were.

6 Again, the assessment was focused on Reg
7 Guide, Rev 2. Really it's applicable to operating in
8 new reactors, and for the purpose of this Reg Guide,
9 those two populations are a little bit distinct.
10 They're sort of different in terms of chemistry, in
11 terms of a few other factors, but ultimately they're
12 both large light water reactors.

13 They have similar neutron fluences.
14 They're still in the same realm of science, but the
15 implications are a little bit different, especially
16 since operating reactors are more focused on extended
17 license periods. New reactors are looking at initial
18 license periods.

19 In terms of where the assessment goes,
20 again, the assessment was not focused on solutions or
21 establishing regulatory positions, and that's why you
22 really don't see it reaching out beyond the Reg Guide
23 and the Reg Guide's results compared to measured data.

24 So a little bit of background, Reg Guide
25 1.99 is entitled radiation embrittlement of reactor

1 vessel materials. It was issued in 1988 based on the
2 data that was available then. It provides predictive
3 curves and supporting calculations of RTndt, which is
4 a measure correlated to the ductile embrittle
5 transition of reactor pressure vessel steels and upper
6 shelf energy, which is a measure of how much energy
7 can be absorbed by those steels when they're of
8 sufficient temperature.

9 It also provides methods that you may
10 utilize to use plant specific surveillance data,
11 including credibility criteria to judge whether that
12 data is properly usable. It also provides a through
13 wall neutron attenuation formula to estimate sort of
14 neutron damage as you go through the thickness of the
15 vessel.

16 And I think this is, one of our members
17 has already pointed out, this is interesting. If you
18 go back to the regulatory analysis that was issued
19 with the Reg Guide -- and I would like to read this
20 quote. I admit, I enjoy it.

21 It says, "There is, however, a strong
22 probability that revisions will continue to be made
23 over the lifetime of the plant as more data are added
24 around the fringes of the database, high nickel
25 materials, low copper modern steels, and high fluence

1 conditions encountered in plant life extension."

2 I like to point this out with the
3 understanding that really the Reg Guide was based on,
4 in a sense, curve fitting to data, and very
5 intelligent people who worked on that curve fit
6 acknowledge that ultimately, you're beholden to the
7 quality and the breadth of your data set for the
8 results, and there was an expectation that over time,
9 as we move beyond the applicability of the original
10 data set, there would be updates.

11 So it really shouldn't be surprising to
12 anyone that here, 30 years later, with dramatically
13 more data than was available when the original Reg
14 Guide was written, that we found that we could do
15 better, so I just, I wanted to point that this isn't
16 -- there is no new magical science understanding.
17 This is ultimately a curve fit and what we have is
18 more data.

19 In terms of what did they have? The RTndt
20 curves were fit to 177 datum. The curves were a mix
21 of Guthrie and Odette results with feathering for the
22 low copper regime. Some of that feathering was
23 essentially motivated by test reactor data. They
24 didn't have data on very low copper steels. No one
25 had it, so --

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1 MEMBER RICCARDELLA: You use the
2 expression "feathering?"

3 MR. WIDREVITZ: Yes, that's actually how
4 it's described in a paper published by one of the
5 original authors.

6 MEMBER RICCARDELLA: And --

7 MR. WIDREVITZ: So essentially they wanted
8 to make sure that the chemistry factors didn't go to
9 zero because of the way their curve fit worked, so
10 they artificially had them saturated at a low value
11 for low value copper. It's an odd description, but
12 that's what occurred. In terms of upper shelf energy,
13 that was -- sorry.

14 MEMBER RICCARDELLA: Would fudged be a
15 better word?

16 MR. WIDREVITZ: Did what we could with
17 what we had, yes, absolutely. The upper shelf energy
18 was developed as upper bound curves. As far as we're
19 able to tell, because you only have what has been left
20 in the written record and these were hand drawn, the
21 credibility criteria and use of surveillance data have
22 no traceable underpinnings as far as we understand it.

23 These were produced by engineering
24 judgment. If you want a fancier word, empirical Bayes
25 comes to mind, and the attenuation formula was based

1 on dpa studies, so this is our background to the Reg
2 Guide as it stands.

3 Now, to analyze this, we really needed to
4 get ahold of newer data, and the best aggregated data
5 source available for this work was a data set called
6 BASELINE produced by ASTM.

7 Many excellent people were involved and
8 this is -- the data, I believe, is up until 2011-ish,
9 so much more up-to-date than the original data set,
10 something like 2,000 data points versus 177.

11 This includes both domestic and
12 international data. About half of it was domestic, so
13 even there, that's 1,000 data points instead of
14 roughly 200, much bigger, more chemistries, more
15 fluences, a very rich data set, and here, I have
16 broken it down by pipes. This is again, just in the
17 assessment report.

18 In terms of results, and I think this is
19 the most significant and interesting plot for the
20 assessment, this is a plot of the predicted shift for
21 each material in terms of how much it embrittles, how
22 much its ductal brittle transition shifts with neutron
23 embrittlement minus the measured value.

24 These are various surveillance capsules
25 and other tested material properties, so it's the

1 residual predicted minus measured. The top plot is
2 for base materials, forgings, and plates. The bottom
3 plot is for welding materials. So the Y-axis is
4 residual. The X-axis is your neutron fluence in our
5 traditional units of neutrons per centimeter squared,
6 energy greater than one mega electron volt.

7 What you see here is your zero is sort of
8 that's what you'd expect if you had a very nicely
9 behaved prediction curve. The two dotted lines are
10 your two sigmas. The red dots are domestic data. The
11 gray dots are international data.

12 What you see here is, certainly if you
13 look at either of these plots, you know, initially at
14 lower fluences, they look fairly well behaved as you'd
15 expect. As we get to higher fluences, some
16 interesting things result.

17 And in terms of the most dramatic result,
18 what you see is that at high fluences for base
19 materials, you start getting these very non-
20 conservative predictions where the measured values are
21 larger than the predicted values.

22 You see that in the domestic data. You
23 see it even more so in the international data that has
24 more high fluence data points. That's a pretty
25 significant result because it's non-conservative and

1 we're very interested in that result.

2 In terms of weld results, whether or not
3 that trend is there, I certainly couldn't tell you.
4 The truth is we don't have as high a fluence for the
5 weld results as we do for the base results.

6 You also see a bit more data, particularly
7 international data, where it's over-predicted compared
8 to the measured data, but any sort of trends just
9 aren't clear there, but certainly for the base data,
10 we have something interesting there.

11 To analyze all of this, we ran it through
12 a whole gamut of statistical tests. Sure.

13 MEMBER RICCARDELLA: The standard
14 deviation lines, are they standard deviation lines
15 based on this data or based on the NUREG 1.99?

16 MR. WIDREVITZ: I believe these are the
17 1.99 standard deviations --

18 MEMBER RICCARDELLA: Okay.

19 MR. WIDREVITZ: -- which I'm about to say
20 are wrong.

21 MEMBER RICCARDELLA: Yeah.

22 MR. WIDREVITZ: So, yeah, but they work
23 reasonably well at low fluences. Again, you know,
24 there's always a question of adequacy. At what point
25 does something become more concerning? And two sigma

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1 is generally accepted practice.

2 MEMBER RICCARDELLA: Each one of those is
3 plus two sigma and minus two sigma?

4 MR. WIDREVITZ: Yes.

5 MEMBER RICCARDELLA: And refresh my
6 memory. At one point, we take into account the
7 standard deviation. What do we add in that? Do we
8 add one sigma or something?

9 (Simultaneous speaking.)

10 MEMBER RICCARDELLA: When you're doing a
11 1.99 estimate of your radiation embrittlement and
12 trying to shift your RTndt, you put back in a factor
13 for the --

14 MR. WIDREVITZ: It's in the margin term.

15 MEMBER RICCARDELLA: Yeah, and what is the
16 --

17 MR. WIDREVITZ: And it's sort of two
18 sigma.

19 MEMBER RICCARDELLA: It's what? It is two
20 sigma?

21 MR. WIDREVITZ: Yeah.

22 MEMBER RICCARDELLA: So you add two sigma
23 back in, all right.

24 MR. WIDREVITZ: Yeah, it's a geometric
25 mean between the uncertainty of your initial squared,

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1 the two times the square root of initial deviation
2 squared plus the standard delta standard deviation
3 squared --

4 MEMBER RICCARDELLA: Okay.

5 MR. WIDREVITZ: -- geometric mean.

6 CHAIR BALLINGER: But what's -- excuse me.
7 What's not on this are the actual values themselves
8 for both the weld and the base metal, and there's a
9 significant difference between those two, right?

10 MR. WIDREVITZ: Yeah.

11 CHAIR BALLINGER: So this shows a
12 significant deviation in the residuals, but as a
13 practical matter, if it's plate material, how close
14 are you to the 41, to the limits are you?

15 MR. WIDREVITZ: Part of the answer to that
16 is that's next steps. The other part is there are
17 high fluence plants that are base limited.

18 CHAIR BALLINGER: Okay.

19 MR. WIDREVITZ: There are some limiting
20 materials up at that fluence and we really, that's
21 where sharpening the pencil and policy implications
22 gets to become key, so we did not want to answer that
23 in the assessment.

24 So statistics, many, many interesting
25 results all together. What you see here are three

1 statistical tests that have been done on a number of
2 bins. The left most column uses all of the U.S. and
3 international data and baseline. The center column is
4 U.S. only. The right column is international data
5 only.

6 The top row is the mean residual. That's
7 sort of the net bias of all results. The middle
8 column is the root mean squared deviation, which is a
9 measure of scatter in a sense, and depending on what
10 mathematical assumptions you make, that's the same as
11 your standard deviation. The bottom row is the log-
12 likelihood, which I explain a little bit more when we
13 get to there.

14 So I'd like to focus really on U.S. only
15 results here for a number of reasons, one of which is
16 one would expect the Reg Guide to perform more poorly
17 for international results because they have different
18 chemistries that really the Reg Guide wasn't built to
19 cover, so it shouldn't be a surprise that it has some
20 interesting effects there.

21 MEMBER MARCH-LEUBA: So you think the
22 difference is the actual physical chemistry of the
23 plant, not the way they reported the data or measured
24 the data?

25 MR. WIDREVITZ: I would say that that's a

1 larger factor.

2 MEMBER MARCH-LEUBA: It's a larger factor,
3 okay.

4 MR. WIDREVITZ: Yeah, in terms of how they
5 measured and reported compared to the fact that
6 there's chemistries that are a fair bit outside of the
7 original 177 data points. It's just second order.

8 So for the U.S. data, what we find is
9 there is overall a mean residual, which is to say that
10 when you sum up all of your residuals, the predictions
11 tend to actually be a little higher than the measured
12 values, which you can see if we -- I'll flip back real
13 quick.

14 If you look at that top plot, it's
15 difficult to see unless you're very close to it, but
16 the residuals actually bow a little bit positive
17 before they bow back down when you get to high
18 fluence.

19 MEMBER MARCH-LEUBA: I say this in every
20 single meeting. You can use the mouse to point and we
21 can follow what you say.

22 MR. WIDREVITZ: You still probably can't
23 see it, but they do. It's much easier to see when
24 you've got much better screens than this. At home,
25 it's totally clear. These monitors have some

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1 saturation effects.

2 And also if you look at, for that matter,
3 welds, they have that same characteristic. Your
4 average residual is positive, which means that your
5 prediction is larger than your measured, and that's
6 exactly what you see when you start -- here we have
7 all of these sub-bins as well and there's a lot of
8 texture here, but they're generally a positive bias.

9 MEMBER KIRCHNER: These are the averages
10 independent of fluence is what you're saying?

11 MR. WIDREVITZ: Yes.

12 MEMBER KIRCHNER: Yeah.

13 MR. WIDREVITZ: Yeah, the bias is
14 interesting. If you have a well-behaved prediction,
15 you would tend to want your residual to be zero, which
16 is to say that you've got a nicely, normally
17 distributed prediction about, that is normal about
18 your data, and clearly these predictions are not, so
19 not the best result in the world, but again, they only
20 had so much data, and now we're using -- we're fitting
21 much -- we're throwing much more data into something
22 that was fit for a smaller data set.

23 Root means squared deviation, I think, in
24 some ways is a more interesting characteristic because
25 it's telling you about how scattered your data is. It

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1 doesn't care whether it's positive or negative. It's
2 interested in just generally what's your scatter?

3 Very tiny and hard to see, these two black
4 lines in here are the standard deviations given in the
5 Reg Guide 1.99 itself, and what you see is in those
6 sub-bins, when you do the calculation using the
7 baseline data set, you actually end up with a larger
8 RMSD, which suggests that the standard deviation of
9 the Reg Guide might be too low. The deviation of the
10 original data set is not consistent with what we've
11 seen as time has gone on.

12 You'll also notice there's two sets of
13 markers, blue and red. I'm mostly talking about the
14 blue markers. Blue markers are just the Reg Guide
15 straight. That's you take the formula and you do your
16 prediction.

17 The red markers have had what's called the
18 degree for degree correction added, which is not
19 common practice for most materials. Basically it was
20 noted somewhat later on that as you go up and down in
21 temperature, your shifts increase or decrease by
22 roughly a degree.

23 So if you go up in temperature, your shift
24 goes down about a degree per degree of going up. If
25 you go down a temperature degree, your shift goes up

1 by a degree, and that's roughly true near the
2 operating temperatures of reactors.

3 This was added later to do some data
4 adjustment and I'll discuss it very briefly in some
5 later slides, but suffice it to say that the Reg Guide
6 doesn't have a temperature term.

7 This is the only temperature adjustment
8 that the NRC has ever discussed, and when you look at
9 it in terms of statistics, it generally reduces the
10 quality of results. It's not well modeling what's
11 going on.

12 MEMBER RICCARDELLA: The degree for
13 degree?

14 MR. WIDREVITZ: The degree for degree when
15 you add it to the Reg Guide causes more modeling
16 issues statistically.

17 MEMBER RICCARDELLA: It reduces the bias.

18 MR. WIDREVITZ: Well, in this case, the
19 bias is higher. If you look at -- the red dots are
20 all above the blue dots in the top row for U.S. data.

21 MEMBER RICCARDELLA: Okay, I had them
22 crossed, all right.

23 MR. WIDREVITZ: Yeah, this is a very
24 information rich set of plots and it's easy to.

25 MEMBER RICCARDELLA: And are there blue

1 dots in the second?

2 MR. WIDREVITZ: They're overlapping.

3 MEMBER RICCARDELLA: Oh, they fall right
4 on top?

5 MR. WIDREVITZ: Yeah, the RMSD is not
6 sensitive to that because it makes some of them -- it
7 moves everything up.

8 (Simultaneous speaking.)

9 MR. WIDREVITZ: The likelihood is -- oh,
10 sorry.

11 CHAIR BALLINGER: Who is this? Oh, it's
12 Dave, okay.

13 MEMBER PETTI: The degree for degree
14 stuff, is this an artifact of this overly complicit
15 model or this is just about the underlying data
16 itself, the fact that there's a greater bias?

17 MR. WIDREVITZ: I think that it's,
18 depending on which material you're talking about, it's
19 complex.

20 MEMBER RICCARDELLA: Dave, this is Pete.
21 The lower temperature you irradiate at in general, the
22 worse it is. If it gets colder, it gets worse, and so
23 when you put this degree for degree adjustment in,
24 you're making at least the lower temperature ones more
25 conservative, right, than they would be without that

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1 correction.

2 MR. WIDREVITZ: Well, higher.

3 MEMBER RICCARDELLA: Hmm?

4 MR. WIDREVITZ: I mean, conservative
5 implies you know truth, but generally, it has the
6 effect of lifting up all of the shifts in the
7 database.

8 MEMBER RICCARDELLA: Yeah, it's raising
9 the bias.

10 MR. WIDREVITZ: Right. Yeah, and I think
11 --

12 MEMBER PETTI: And something to get a
13 sense on, is it really something in the data or is it
14 something in the manipulation of the data, that if
15 you, you know, plot it all over again and get
16 everything in a Machiavellian approach, would you get
17 better answers? Is it just an artifact of the
18 construct or if it in the data itself?

19 MR. WIDREVITZ: If it was in the data, it
20 wouldn't do this to the bias.

21 MEMBER RICCARDELLA: Well, it is a multi-
22 variant approach with a whole bunch of variables.
23 It's just that radiation temperature isn't one of
24 them, that it should have been probably, but there's
25 other variables, chemistry factors and those types of

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1 things. So it is a multi-variant approach in 1.99,
2 but it's just that temperature wasn't one of those
3 variables.

4 MR. WIDREVITZ: Yeah, I mean, this is
5 moving a bit beyond the assessment, but I think you'll
6 find if you look at nearly any more modern trend curve
7 effort, they have either a temperature term or
8 something that is equivalent to temperature in the
9 data.

10 MEMBER RICCARDELLA: Yeah, yeah.

11 MR. WIDREVITZ: So that's something that's
12 been recognized. And again, we're talking about 30
13 years ago, they only had 177 data points. When you
14 add more variables to a fit and you attempt to fit it
15 on your database, eventually you're running out of the
16 quality degree of freedoms you need to fit, and so you
17 get into mathematical convergence issues.

18 So this, yeah, I'm not going to sit here
19 and tell you there shouldn't be a temperature turn.
20 There should have been, but this one in particular
21 causes statistical issues.

22 MEMBER REMPE: So for the temperature
23 corrections, you can see, I guess, there's a point
24 that's the fourth in the U.S. data only that has the
25 largest variation because you did include that

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1 temperature correction. How much of a correction was
2 there? Is it 20 degrees? Is it 100 degrees or do you
3 have any idea on --

4 (Off microphone comments.)

5 MEMBER REMPE: Well, that's a residual, so
6 is --

7 MR. WIDREVITZ: An average of seven --

8 MEMBER REMPE: So an average --

9 MR. WIDREVITZ: -- from the residual.

10 MEMBER REMPE: -- was the residual. So if
11 you had something that you had a plant, like an
12 advanced reactor running at considerably more, you
13 might see a larger increase is what I'm asking that
14 question for.

15 MR. WIDREVITZ: Well, advanced plants are
16 much hotter than --

17 MEMBER REMPE: Well, one is maybe not.
18 That's a PWR running at a BWR.

19 MR. WIDREVITZ: Well, the short answer is
20 there's a DCD called NuScale that's outside the
21 temperature range of Reg Guide 1.99 that's much
22 cooler.

23 MEMBER REMPE: That's what I'm trying to
24 get to. So it would have a much larger correction,
25 right?

1 MR. WIDREVITZ: Degree for degree is not
2 satisfactory for NuScale. It wouldn't give you
3 accurate results.

4 MEMBER REMPE: Okay.

5 MEMBER RICCARDELLA: What's their vessel
6 temperature?

7 MR. WIDREVITZ: I want to say 494, 96, and
8 the Reg Guide states that it's accurate between, I
9 believe, 525 and 590.

10 MEMBER RICCARDELLA: I've got to assume
11 that they'd be pretty judicious in their material
12 chemistry choices though.

13 MR. WIDREVITZ: Yeah, that's the flip
14 side. All new reactors have very low copper. Copper
15 is our main culprit here. So there is a very mix and
16 match going on with NuScale.

17 MEMBER RICCARDELLA: Yeah.

18 MR. WIDREVITZ: Okay, so we'll get to log-
19 likelihood. The log-likelihood is a very interesting
20 statistic that brings in a lot of the characteristics
21 of other tests. In essence, it answers the question
22 of if I have a formula, what is the likelihood I would
23 come up with this data set?

24 And the higher the number, the more likely
25 your data set would have been generated by that

1 formula. So what you see here is at the top, zero.
2 At the bottom is negative 85,000.

3 The magnitude of log-likelihood is related
4 to the formula's constructions. The magnitude is not
5 meaningful. It's almost, in a sense, it's a
6 qualitative measure in that, you know, a larger
7 negative value is worse. It's less likely that you
8 found a good fit.

9 People use log-likelihood as one of the
10 parameters to make fits, and so that's part of why
11 it's here is that it brings in a lot of interesting
12 information, and what you see is generally the results
13 across the board for USA are not great.

14 Degree for degree increases that trend for
15 a lot of data sets, though it improves it a little bit
16 for welds -- and high copper.

17 It's complex, but generally speaking, and
18 certainly for the total baseline, Reg Guide 1.99 does
19 not work well for international data, and you see that
20 when you try to add U.S. and international data all
21 together in a log-likelihood calculation, and for
22 international, you see that degree for degree just
23 absolutely doesn't work, which is interesting, but a
24 little bit outside of our core concern here.

25 Any questions? Yeah, I find log-

1 likelihood is sufficiently complex that you sort of
2 have to just use it.

3 Okay, finally, because three is not good
4 enough, we have a fourth statistical test, the student
5 T test. The student T test essentially asks when I
6 compare these two sets of information, what is the
7 likelihood that their means are the same?

8 And so in student T, if you get a value of
9 the T statistic below 1.96, then you've got a 95
10 percent confidence that your means are similar, that
11 these two distributions may actually be related to
12 each other strongly enough that you can consider them
13 the same. This 1.96 is almost a two sigma kind of
14 criteria.

15 So what you see in these plots is 1.96 is
16 green. It's that green segment at the bottom. I'm
17 not sure -- yeah, you can't see it on the televisions,
18 but it's in the document. It's just below the two.

19 And what you do is, in this case, you take
20 the T statistics of each input variable or potential
21 input variable, which are on the bottom of these
22 plots, copper, lot of fluence nickel, temperature,
23 phosphorus, manganese, lot of flux, and we took a look
24 to see, you know, does it seem likely that, looking at
25 the residuals, that this modeling variable has been

1 well modeled by what the T statistic is sensitive to
2 by Reg Guide 1.99, and what we find is that some
3 variables seem to do all right, nickel, phosphorus.

4 You know, again I'm going to the center
5 column which is U.S. data only. Nickel, phosphorus,
6 and manganese do all right. There is some concerning
7 residuals in copper, in fluence, a big one in
8 temperature, not a surprise. Reg Guide 1.99 doesn't
9 have a temperature term, one for lot of flux.

10 As far as the T statistic is concerned, if
11 you apply the degree for degree transformation, you
12 get the bottom row of plots. That improves your
13 residuals for the T statistic, except for copper,
14 which gets worse, and given that copper is our primary
15 contributor to embrittlement, that's an unfortunate
16 result.

17 What you'll see in the T statistic is
18 international data has a lot of bad residual behavior,
19 which is what you'd expect because you really wouldn't
20 expect the Reg Guide to handle the full gamut of
21 international data particularly well because it wasn't
22 designed to.

23 So there is also a great deal of subtlety.
24 We've also plotted the sub-bins in other colors. It's
25 very difficult to read on these screens, but suffice

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1 it to say that there is a great deal of texture in
2 sub-bins, and that's something that is very difficult
3 when you're trying to create one curve to cover many
4 chemistries and potentially mechanisms and you'll find
5 that it works better for certain materials than others
6 when you've got this sort of broad general curve.

7 All right, so what are our results? Let's
8 try to summarize. The primary deficiencies, the
9 deficiencies that certainly me, personally, I think
10 warrant a little bit of attention, number one, non-
11 conservative high fluence results for the base metals.

12 I couldn't really tell you today whether
13 there is something similar for welds or not, but
14 certainly for the base metals, I'm concerned about the
15 accuracy of the predictions for them at high fluences.
16 I'm also, as a new reactor person, concerned about the
17 low copper results.

18 If you ask me what does that mean, I would
19 say the Reg Guide 1.99 assumes a certain shape
20 function of embrittlement. What does the curve look
21 like as you embrittle? Low copper materials have a
22 different shape function from Reg Guide 1.99.

23 I'm a new reactor guy. I see a lot of low
24 copper materials. There's an inaccuracy there that
25 concerns me from a technological level. It's an

1 accuracy question. I don't like the accuracy that I'm
2 getting from that. Again, this isn't a policy
3 significance thing. It's simply an accuracy
4 statement.

5 In terms of secondary deficiencies, things
6 that either go along or aren't quite as concerning, it
7 seems that the standard deviations stated in the Reg
8 Guide is a bit too low when you look at a more modern
9 data set.

10 You've got a conservative bias in low to
11 mid fluences, which means you're over predicting your
12 embrittlement a little bit, and there's a lack of
13 temperature adjustment. When you're talking about a
14 degree for a degree, there's quite a lot of
15 information that's being hidden by the fact that there
16 isn't normally a temperature term in there.

17 For reactors that run hotter, that's to
18 their detriment. For reactors that run cooler, that
19 might push their values up, but in general, again,
20 from an accuracy standpoint, this is a clear
21 inaccuracy. It's reducing the accuracy of my
22 prediction.

23 MEMBER RICCARDELLA: Do any licensees
24 actually use the degree for degree method?

25 MR. WIDREVITZ: The degree for degree

1 method is used for adjustment for sister plant data.

2 MEMBER RICCARDELLA: For which?

3 MR. WIDREVITZ: For sister plant data.

4 When you've got heat matched welds in different places

5 --

6 MEMBER RICCARDELLA: Yeah.

7 MR. WIDREVITZ: -- and you want to pull

8 the data together to use --

9 MEMBER RICCARDELLA: Yeah, but if I have

10 a plant and I wanted to estimate what my shift is, and

11 I know I'm at a different temperature than the mean

12 temperature of the data, would I adjust for that?

13 MR. WIDREVITZ: If you have plant specific

14 data, you probably wouldn't. If you have your own

15 plant materials --

16 MEMBER RICCARDELLA: Your own --

17 MR. WIDREVITZ: -- and your own capsules,

18 and you're within the temperature bands in the Reg

19 Guides, you're not directed to use it.

20 MEMBER RICCARDELLA: Okay.

21 MR. WIDREVITZ: And so that's an accuracy

22 -- obviously your accuracy is lower because of that.

23 MEMBER RICCARDELLA: Yeah.

24 MR. WIDREVITZ: I'm not saying

25 significance. I'm just saying the accuracy of your

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1 prediction.

2 To give some context on a calendar year,
3 and I have to caution everybody, the data used to
4 produce these curves were, in a sense, the fluence of
5 capsules that were marked as end of license capsules
6 and not extended license capsules, those capsules are
7 not required to match the end of license licensing
8 basis fluence.

9 Those capsules could be a bit higher than
10 what you predict to actually hit at the end of 40 or
11 60. So consequently, these results are a little bit
12 ahead on average of the actual fleet's materials
13 because the data was gathered from industry reports on
14 capsules essentially because it was all in one place,
15 and so this is a little bit ahead of what you're going
16 to see in the plant's relative licensing basis.
17 Having said that --

18 MEMBER RICCARDELLA: The capsules lead the
19 vessel, right?

20 MR. WIDREVITZ: The capsules lead the
21 vessel, but also the fluences you pick might be in
22 excess of actually your 40-year fluence, so your 40-
23 year capsule might be a 45-year fluence. That's
24 allowable by the ASTM E-185, and so this is a little
25 bit -- these dates are probably a little bit earlier

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1 than if you went through and went through all hundred-
2 ish plants and looked at their actual licensing bases.

3 So what I've plotted here is three sets of
4 when materials, when we're forecasting leading
5 materials to hit three different fluences, 3e times 10
6 to the 19th, which I would call sort of the mean
7 deviate, where if you look at the plot of base
8 materials, that mean begins deviating from zero in a
9 non-conservative way is around 3 times 10 to the 19th
10 neutrons per centimeter squared. That's the white
11 dots, and you can see there's already plants with
12 materials at that fluence.

13 If you go to 6 times 10 to the 19th, which
14 is about where the mean hits the two sigma line,
15 that's still in the future, 2020 sometime, but plants
16 will be reaching that, and this is all ID fluence.

17 And then I've plotted 8 times 10 to the
18 19th because it looked nice and it was sort of
19 interesting to give you a little bit of character to
20 the data and a little bit of context.

21 So really, you're looking at, in terms of
22 accuracy, you're going to start getting concerned
23 about how accurate your base metals are in 1.99 in the
24 late 2020s give or take, which kind of helps you think
25 about when you need to do what sort of work if you're

1 concerned about those inaccuracies, and these are
2 counts based, again, on these capsule fluences at the
3 two different sort of arbitrary fluences that I picked
4 to plot.

5 I'm not going to say there's anything
6 mathematically magical about these. Again, you really
7 have to think about what you're constructing in your
8 guidelines, what do you want to call significant, et
9 cetera.

10 So let's go to upper shelf. In terms of
11 upper shelf, we took data from the data set, which is
12 surveillance capsule reports essentially. We combined
13 it with properties from baseline which has all of your
14 various chemistries and such, and we came up with a
15 dramatically larger data set than was available when
16 Reg Guide 1.99 was developed. We're talking about on
17 the order of 1,200 data points, the vast majority of
18 which, 1,000, were U.S. data points, so very relevant.

19 The international data always is
20 interesting because they're a little, some of them are
21 outside of necessarily what Reg Guide 1.99 is. Some
22 of them are more similar to what we'd expect with new
23 reactors, so it's always interesting to gather a rich
24 data set to get rich results.

25 The REAP data set, again, you know,

1 everything is a snapshot in time. The REAP data set
2 has data included up to about five or seven years ago,
3 so again, there's been a few added, but not a huge
4 number in terms of data, so this is reasonably
5 representative of what we understand today really
6 domestically.

7 So in terms of results, this is a plot
8 from, I believe, a PVP paper by Mark Kirk. The
9 original construction of upper shelf energy was to be
10 a bounding curve, and what we found is when you look
11 at more modern data sets, in this case, he had 860-ish
12 data at that point, about 19 percent of the data are
13 above the curve. The measured is higher than the
14 predicted.

15 So it's not working as was originally
16 designed, but it's still certainly, by no means is it
17 a mean trend, right. We're still talking about
18 something that's a fairly conservative prediction to
19 the data set.

20 In terms of results, if you look
21 statistically, there's a significant positive bias
22 when you look at the data. It's supposed to be a
23 bounding curve, so that's exactly what you'd expect.
24 The RMSD is positive, again, not particularly
25 surprising given the design of the curve.

1 When you look at the T statistic, there's
2 quite a bit of modeling residual along various
3 involved variables. This isn't a surprise generally.
4 Upper shelf energy is more difficult to predict with
5 accuracy than RTndt. This is a result that we've seen
6 many, many times. So could it be improved? Yes.

7 In terms of use results, when do we really
8 get interested? So, again, this isn't policy. We had
9 to, to a certain extent, find a curve, choose to
10 believe it a little bit more, and look at the results.

11 What you're concerned about is when you're
12 looking at upper shelf energy, your regulatory
13 requirement is you'd like to remain about 50 foot
14 pounds, and if you go below 50 foot pounds, then you
15 have to go and do an equivalent margin analysis, and
16 to date, no one has failed to succeed at equivalent
17 margin analysis, so this is not a hard regulatory
18 limit. It's more of a, "This is where you need to pay
19 a little bit more attention," regulatory method.

20 So what you see in this plot is everything
21 to the left of that red bar is materials that have
22 been predicted to fall below 50 foot pounds at some
23 point. The blue curve is sort of where your
24 measurements are showing you things that are below 50
25 foot pounds.

1 And the materials of greatest interest are
2 the materials where your measurements would tell you
3 you're below 50 foot pounds or sort of your synthetic,
4 whichever new slightly better curve you're hopefully
5 finding tells you that maybe you should do an
6 equivalent margin analysis, but the current one does
7 not, and there's just a handful, a tiny percentage of
8 the databases falling into that quadrant.

9 MEMBER RICCARDELLA: Everything to the
10 left of that vertical red line would have required a
11 margin analysis based on the prediction, right?

12 MR. WIDREVITZ: Yes.

13 MEMBER RICCARDELLA: And then -- okay, and
14 then everything --

15 MR. WIDREVITZ: It's difficult to see on
16 the television, but this quadrant here in dark blue is
17 really where --

18 MEMBER RICCARDELLA: Yeah.

19 MR. WIDREVITZ: -- where --

20 MEMBER RICCARDELLA: Those are the ones of
21 concern.

22 MR. WIDREVITZ: -- you might be in a space
23 where maybe you should have done an equivalent margin
24 --

25 MEMBER RICCARDELLA: Yeah.

1 MR. WIDREVITZ: -- but you have not yet,
2 and you can see there's just a handful.

3 MEMBER RICCARDELLA: Yeah.

4 MR. WIDREVITZ: Very small numbers. So
5 again, this is sort of a sort criteria too. So what
6 is your -- at this point, you can draw your own
7 conclusion in terms of level of significance.

8 MEMBER RICCARDELLA: You know, this type
9 of a plot enables you to understand whether there are
10 some safety concerns with the upper shelf prediction.
11 Couldn't you do an equivalent plot like this for the
12 delta RTndt?

13 I mean, what you did for the delta RTndt
14 just estimated, you know, bias and accuracy, and
15 didn't really give me a feel for whether there is a
16 concern, whether someone who had been using 1.99, if
17 one of these data points represented a plant and
18 somebody had done the 1.99 evaluation, and they'd be
19 off by a significant number of degrees from what the
20 actual --

21 MEMBER MARCH-LEUBA: In a sense, the
22 previous analysis, the student T test still uses a
23 statistical significant error, but it can still be a
24 one percent error and be completely irrelevant --

25 MEMBER RICCARDELLA: Yeah.

1 MEMBER MARCH-LEUBA: -- from a physical
2 point of view.

3 MEMBER RICCARDELLA: Yeah.

4 MEMBER MARCH-LEUBA: So, yeah, I agree
5 with --

6 MR. WIDREVITZ: There's a lot of
7 interesting ways to approach the question. The first
8 one is we were not looking at licensing effects.

9 MEMBER RICCARDELLA: Well, but you are
10 with this plot.

11 MR. WIDREVITZ: Well, this one is very,
12 very easy.

13 MEMBER RICCARDELLA: Yeah.

14 MR. WIDREVITZ: When you're using RTndt,
15 you're talking about shifting pressure temperature
16 limits --

17 MEMBER RICCARDELLA: Yeah.

18 MR. WIDREVITZ: -- which is a fairly
19 sophisticated thing.

20 MEMBER RICCARDELLA: Yeah.

21 MR. WIDREVITZ: You're talking about your
22 PTS criteria, so it's more complicated than the way
23 that the NRC has traditionally used upper shelf energy
24 results. If you'd really like to answer that question
25 and you're starting to lean towards doing

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1 probabilistic fracture mechanics results like you see
2 in the basis for 5061A for example, and so the size of
3 the question grows very large and now you start
4 talking about you have to get into licensing basis, of
5 which there are roughly 100, for example.

6 MEMBER RICCARDELLA: Well --

7 MR. WIDREVITZ: And so it's certainly an
8 interesting question and I think it's something that,
9 as we move forward, we're thinking about.

10 MEMBER RICCARDELLA: But I predict the
11 delta T RTndt based on 1.99 with the margin term and
12 with everything in there, and then I say okay, now
13 based on the real data, what is that real delta T
14 RTndt for each specific data point, and --

15 MEMBER MARCH-LEUBA: Open to slide 10, the
16 one with a lot of data. Keep going, keep going, keep
17 going, that one. Okay, if we look at the USA data
18 only, the middle one, and look at the difference
19 between the black line, just the predicted, and this
20 was the actual, that is the error, isn't it?

21 MR. WIDREVITZ: The difference between the
22 black line and the actuals is the error in standard
23 deviation.

24 MEMBER MARCH-LEUBA: Sure, which is the
25 error.

1 MR. WIDREVITZ: Which is a measure of your
2 -- yeah, a measure of how broad your normal --

3 MEMBER MARCH-LEUBA: So I'm reading it to
4 be like five degrees? Would you agree?

5 MR. WIDREVITZ: Roughly.

6 MEMBER MARCH-LEUBA: Right, and what, I
7 have no idea what five degrees in RTndt means, but
8 what real data with 1,000 points means is five degrees
9 higher than what the Reg Guide says.

10 MEMBER RICCARDELLA: Well, that's just the
11 standard deviation.

12 MEMBER MARCH-LEUBA: On average, there is
13 five degrees more error.

14 MEMBER RICCARDELLA: Yeah, but is that
15 error conservative or not conservative? I think there
16 would be a way to make a plot that would show that.

17 MEMBER MARCH-LEUBA: But what I have no
18 idea is that the five degrees does --

19 (Simultaneous speaking.)

20 MEMBER RICCARDELLA: Well, the five
21 degrees C is 10 degrees Fahrenheit. That can be --
22 that's significant.

23 MEMBER MARCH-LEUBA: Celsius, Celsius.

24 MEMBER RICCARDELLA: That can be
25 significant.

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1 MR. WIDREVITZ: This is all in Celsius.

2 MEMBER RICCARDELLA: Huh?

3 MR. WIDREVITZ: All of these plots are in
4 Celsius.

5 MEMBER RICCARDELLA: Yeah, yeah.

6 MR. WIDREVITZ: So it's more in
7 Fahrenheit.

8 MEMBER MARCH-LEUBA: And this is --

9 MR. WIDREVITZ: I agree with you. It
10 would be very interesting, and I think that as we move
11 forward, those are exactly the sort of questions that
12 we need to answer internally in terms of when you get
13 into licensing basis, you start seeing use of plant
14 specific data. You see, you know, what are the
15 methodologies used to generate the pressure
16 temperature curves?

17 You know, I've had conversations about how
18 thick is the line you drew on your pressure
19 temperature limit? Is that your error bar? There's
20 many, many factors and the complexity of the
21 discussion increases geometrically.

22 MEMBER RICCARDELLA: Yeah, but, you know,
23 I don't necessarily want to take it all the way to PT
24 limit curve. I'm just thinking in terms of delta
25 RTndt. Each one of these data points in this big

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1 scatter plot, you could assume that's a plant, or a
2 base metal or weld metal in a plant, and then you say,
3 well, for that data point, if I had used Reg Guide
4 1.99 to predict what its delta T RTndt would be, where
5 does it lie relative to what the measurement actually
6 shows?

7 MEMBER MARCH-LEUBA: That is the previous
8 slide, the red dots provided there?

9 MEMBER RICCARDELLA: No, yeah, but, see,
10 that's the residual. That's not the actual -- that's
11 not the prediction. That's the residual.

12 MEMBER MARCH-LEUBA: That's the error on
13 the calculation.

14 MEMBER RICCARDELLA: The error relative to
15 zero, yeah, but is the error biased? You know,
16 remember, there was a bias, and is the bias -- I don't
17 know.

18 MEMBER MARCH-LEUBA: It's a little larger
19 --

20 MEMBER RICCARDELLA: I'm not expressing
21 myself well. I think you could make a plot which
22 shows how conservative or non-conservative your
23 predictions would be for each of these data points.

24 MR. WIDREVITZ: When you plot that off the
25 raw data, you end up with a plot with 1,800 data

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1 points that's uninterpretable by eye, but I agree. I
2 mean, there's certainly -- you can express that and we
3 chose to use the residuals because it provides, number
4 one, it gives you sort of an overall picture, and
5 number two, you can actually understand it using the
6 human eyeball.

7 MEMBER RICCARDELLA: I'm not arguing that
8 the Reg Guide doesn't need to be revised. I think it
9 should be revised. It was based on 180 data points
10 and now we have 2,000. I mean, that's a no-brainer,
11 right? But the question is do we have a significant
12 safety concern --

13 MR. WIDREVITZ: Yes, absolutely, and that
14 is --

15 MEMBER RICCARDELLA: -- at this point in
16 time?

17 MR. WIDREVITZ: That is next steps.

18 MEMBER RICCARDELLA: And I think we should
19 do some analyses. We could do some quick analyses to
20 see that.

21 MEMBER MARCH-LEUBA: Yeah, the question on
22 my mind is do I have to call these guys and say they
23 need to find you tomorrow to do this because this is
24 a serious concern or can we wait a couple of years?

25 MR. MITCHELL: And this is Matt Mitchell.

1 (Off-microphone comments.)

2 MEMBER RICCARDELLA: Okay, sorry.

3 MR. MITCHELL: I mean, this is Matt
4 Mitchell, Chief of the Materials and Chemical
5 Engineering Branch at NRO.

6 So, yes, I think we completely agree with
7 what you're saying, that the assessment of the
8 importance of the difference in the models between Rev
9 2 and any model that one might choose, a more modern
10 model if you'd like to call it that, needs to be
11 assessed, its significance from a regulatory
12 application standpoint in terms of what does it mean
13 for affecting potentially the safety understanding of
14 some plants.

15 That will need to be assessed, but I think
16 we're just saying we're not -- we haven't done that
17 step yet. This is an evaluation. This was attempted
18 to be a technology, if you will, centric evaluation to
19 just look at whether the error might exist, but you're
20 absolutely right. That step is essential in terms of
21 where we go from here.

22 MEMBER RICCARDELLA: But it seems to me
23 that you've taken that step for upper shelf energy by
24 creating that plot with the blue zone, and you haven't
25 tried to do something similar to that for delta RTndt.

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1 MR. MITCHELL: And I guess it turns out
2 that way because in a sense, upper shelf energy is
3 sort of an isolated parameter, right? It's just a
4 measure of where is the upper shelf energy?

5 When you get to understanding the shift
6 and the models for the shift in the transition
7 temperature, then you have to get back into coupling
8 that along with the understanding of the initial
9 RTndt, the margin term.

10 So it becomes a more complex calculus, if
11 you will, to put it all together to end up with sort
12 of a regulatory understanding, at least, you know, in
13 relationship to our normally understood parameters for
14 how we measure, you know, the imputed safety of a
15 reactor vessel.

16 So because it's a little more complicated
17 calculation, this ends up being just a piece of the
18 greater overall picture, where when you look at upper
19 shelf energy, you can't really represent it in any way
20 other than basically to just represent the entire
21 story.

22 So I think that's, I guess that's the
23 fairest way I could say it, and we did not intend, or
24 the intent, at least at this time, wasn't really to
25 try to make a statement about the regulatory

1 application part of it, but I think just in upper
2 shelf energy space, I don't think there's any way you
3 could represent the data without sort of making that
4 obvious.

5 MEMBER RICCARDELLA: Okay.

6 MEMBER MARCH-LEUBA: There's a five-second
7 rule around here. You keep going if we don't say
8 anything.

9 MR. WIDREVITZ: Okay, so, yeah, it's --
10 that's how we judge upper shelf energy. It's really
11 the only basis to talk about it in terms of the way
12 that it exists and the way we use it, so.

13 MEMBER MARCH-LEUBA: And the conclusion
14 you give for that is we don't have any problem with
15 delta use?

16 MR. WIDREVITZ: I think my conclusion is
17 that -- could it be more accurate? Yes.

18 MEMBER MARCH-LEUBA: But --

19 MR. WIDREVITZ: Am I going to spend money
20 on it?

21 MEMBER MARCH-LEUBA: If it was your money,
22 you wouldn't spend it.

23 MR. WIDREVITZ: Yeah, I wouldn't spend my
24 money on it. Dan Widrevitz wouldn't spend his money
25 on this.

1 MEMBER RICCARDELLA: Yeah, but if you go
2 to the next slide, I look at your last bullet or the
3 thing below the bullet. It says you evaluated to say
4 that minimal impact to safety criteria as supported is
5 known to be extremely conservative, and yet we haven't
6 tried to make a statement like that about the delta T
7 RTndt. Anyway, I've made my point.

8 So in terms of primary deficiencies, we
9 have a limited number of materials that are projected
10 to remain above 50 foot pounds and not trigger EMAs.
11 The delta use predictions are not bounding as
12 originally designed.

13 I feel very comfortable saying minimal
14 impact from a statistical point of view. You know,
15 there are so few materials that fall into the zone of
16 interest that's built around this topic that there's
17 no mathematical basis for me to tell you that there's
18 issues essentially.

19 When I try to apply statistics, what I
20 find is it more or less works as designed even though
21 it's not doing exactly what they thought it would.

22 MEMBER RICCARDELLA: Even though there's
23 just as much residual and scatter as there was in the
24 other?

25 MR. WIDREVITZ: Well, and I'd say it was

1 worse for upper shelf, but it was worse back then too,
2 and so they constructed --

3 MEMBER RICCARDELLA: Yeah.

4 MR. WIDREVITZ: -- broader criteria for
5 it.

6 MEMBER RICCARDELLA: Okay.

7 MR. WIDREVITZ: So speaking of criteria,
8 the credibility criteria, there are five paragraphs
9 that are numbered in the Reg Guide called credibility
10 criteria, and they're what you have to, in essence,
11 weigh plant specific data against if you want to get
12 a little bit of margin credit and to improve your fit
13 potentially.

14 They're written fairly open-endedly. I
15 use the word vague. They're open to interpretation
16 the way they're written. If your data is not deemed
17 credible, your data is not considered.

18 The criteria compare your measured data to
19 a refit chemistry factor for Reg Guide 1.99's
20 prediction result, which essentially says try to jam
21 Reg Guide 1.99's shape function to your data and take
22 a look.

23 Run it through my credibility criteria and
24 if it comes out right, if your data ends up looking
25 like it's got about the shape function of Reg Guide

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1 1.99, all right, here's some credit to your margin,
2 and that's it, and as a new reactor guy and as sort of
3 a bit more of a technology focused person, I feel like
4 that's maybe not the question I wanted asked.

5 In terms of how to even use it, it was
6 sufficiently difficult. The staff had a fairly
7 lengthy presentation in 1998, which has since been
8 used by many people, that provided perspective on the
9 information of vague credibility criteria among other
10 data use issues.

11 One of the statements in that presentation
12 which is not in the Reg Guide is that you can, if you
13 have a single outlier in your plant-specific data,
14 that's okay. It can still be credible, which is not
15 in the Reg Guide, so clearly people have had problems
16 with credibility here for quite a long time.

17 So to investigate this, we wanted to try
18 and do something at least somewhat numerical other
19 than pointing out that it's constructed to answer a
20 question that maybe isn't the most interesting
21 question, that it's got vague criteria.

22 We essentially said, well, we're going to
23 do a single outlier test. We're going to do a Monte
24 Carlo algorithm where you begin with material with
25 properties defined exactly as the Reg Guide defines

1 them, with a standard deviation exactly as the Reg
2 Guide defines.

3 We're going to simulate a number of
4 materials, of chemistries, low, medium, and high
5 copper essentially. Here I have reproduced the high
6 copper plot, and we're going to see how many of these
7 simulated Monte Carlo data sets would have been deemed
8 credible.

9 And these are materials that should be
10 deemed credible because they're constructed exactly
11 according to the Reg Guide. Now, obviously with
12 standard deviation and normal curves, you'd expect
13 some --

14 MEMBER MARCH-LEUBA: You used normal
15 distributions?

16 MR. WIDREVITZ: We used normal
17 distributions.

18 MEMBER MARCH-LEUBA: Yeah. That's the
19 problem. Is the normal distribution is not physical
20 when it goes to service under the agent.

21 But sometimes you roll a random number
22 that has two other standard deviations.

23 MR. WIDREVITZ: You'd expect to have
24 rejects.

25 MEMBER MARCH-LEUBA: The real -- real life

1 does not go to 12 standard deviations. Normal
2 distribution should be capped at three.

3 (Off-microphone comments.)

4 MEMBER MARCH-LEUBA: Yeah. Anyway, that's
5 a -- a sore point with me.

6 (Laughter.)

7 MR. WIDREVITZ: I could -- we could speak
8 for hours about my opinion about the flippant use of
9 normal distributions.

10 MEMBER MARCH-LEUBA: Um-hum.

11 MR. WIDREVITZ: But suffice it to say that
12 -- that I think for the purposes of this
13 demonstration, it was adequate.

14 We did a thousand runs. And so, in this
15 somewhat complicated plot, what you see, the most
16 important part is in a high copper weld when you take
17 surveillance capsules, those go to your surveillance
18 program.

19 You're going to have five capsules at this
20 copper due to your predicted embrittlement. As you
21 pull them, the top line that says credible, so yeah,
22 credible chemistry factors, would you actually use
23 your own data for material that should be highly
24 consistent with the Reg Guide's instruction.

25 And as you pull the capsules, what's the

1 chance in a Monte Carlo simulation of you getting your
2 data to be incredible?

3 When you pull your first capsule, you need
4 two capsules to use your data at all. There's a 97
5 percent chance that, yes, your data will be credible,
6 you fit it to your data. You get a result.

7 You pull your third capsule, now it's down
8 to 86. That's interesting. Pull your fourth capsule,
9 it's down to 65. That's not really what you should be
10 expecting.

11 You get to your fifth capsule, you have a
12 40 percent chance of surviving the credibility
13 criteria with the material that works perfectly
14 according to the construction of the Reg Guide.

15 That just does not strike me as good
16 behavior for a system.

17 MEMBER MARCH-LEUBA: Describe again the
18 credibility test you're running. How do you do the --
19 that idea?

20 How do you know all the way the
21 credibility continue?

22 MR. WIDREVITZ: So in this case the --
23 what you do is you take -- you take the stated -- you
24 adjust your chemistry factors using linearly squares.

25 So you've refit, tried to refit your

1 shaped function to surveillance data.

2 MEMBER MARCH-LEUBA: You roll a thousand
3 times the dice, --

4 MR. WIDREVITZ: Um-hum.

5 MEMBER MARCH-LEUBA: And get the thousand
6 measurements. But --

7 MR. WIDREVITZ: At each capsule.

8 MEMBER MARCH-LEUBA: Yeah. For each
9 capsule. You have a thousand capsules for each
10 capsule, right?

11 MR. WIDREVITZ: I believe, so Matt Gordon
12 actually performed the code. I believe that's how it
13 worked, is that it sampled the distribution at each
14 capsule using the standard deviation, using a normal
15 function.

16 MEMBER MARCH-LEUBA: Correct.

17 MR. WIDREVITZ: And so -- and not the same
18 normal function each time. So resample that each
19 capsule pull for each Monte Carlo run.

20 MEMBER MARCH-LEUBA: You roll a random
21 number and then sample from the distribution.

22 MR. WIDREVITZ: Yes.

23 MEMBER MARCH-LEUBA: But keep going.

24 MR. WIDREVITZ: Yeah. And so it's got the
25 normal distribution. Share the same characteristics

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1 as assumed by the Reg Guide.

2 So you would expect much better, much
3 better credibility results in the end.

4 MEMBER MARCH-LEUBA: How do you -- how do
5 you determine the capsule is not credible?

6 MEMBER RICCARDELLA: Well, if you have a
7 few outliers.

8 MR. WIDREVITZ: Okay. So to determine
9 it's not credible is that the standard deviation is
10 greater than that given in the Reg Guide in the
11 credibility criteria.

12 So it's a very strict interpretation.
13 Which is the strictest interpretation --

14 MEMBER MARCH-LEUBA: Okay.

15 MR. WIDREVITZ: Of the credibility
16 criteria as written. And obviously Wichman tells you
17 you can have one outlier for example.

18 So if you're following not the Reg Guide,
19 but the presentation, these results would be somewhat
20 better. But given that just from the very basic
21 instruction of them, they're causing these
22 mathematical issues.

23 This is sort of an interesting and
24 insightful result. You know, and if you go in a --
25 sorry.

1 MEMBER RICCARDELLA: To me, you know, the
2 credibility criteria is, how well does your data fit
3 Reg Guide 1.99?

4 MR. WIDREVITZ: Yes.

5 MEMBER RICCARDELLA: And if it doesn't,
6 then you have to use Reg Guide 1.99. It's
7 counterintuitive.

8 MR. WIDREVITZ: It's the opposite of the
9 question I would pose.

10 MEMBER MARCH-LEUBA: You might as well use
11 Reg Guide 1.99 to start with. Because it either fits
12 it, or you use it.

13 MR. WIDREVITZ: Sure.

14 MEMBER MARCH-LEUBA: Why bother with
15 something?

16 MR. WIDREVITZ: Well, if you have credible
17 data, and it's worse than Reg Guide 1.99, but has the
18 same shape function, then you have to use that.

19 MEMBER RICCARDELLA: Yeah. You have to
20 use it.

21 MR. WIDREVITZ: But if you have, you know,
22 for example there's 50.61(a) that the NRC has
23 endorsed. It has a different shape function.

24 And if you look in the assessment, we
25 completed the same simulations but used 50.61(a) as

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1 our true, our state of true. And then sampled from
2 it.

3 What resulted is that you reject even more
4 credible data despite the fact that you generally have
5 a material that's embrittling in a different way.

6 MEMBER RICCARDELLA: But 50.61(a), is that
7 the PTS?

8 MR. WIDREVITZ: That's the alternate.
9 Yeah.

10 MEMBER RICCARDELLA: The alternate, PTS
11 rule.

12 MR. WIDREVITZ: And so we know for at
13 least some material out there, that one's more
14 accurate.

15 MEMBER RICCARDELLA: So have you tried to
16 do this study with that prediction instead of 1.99?
17 Just the stat -- forget the -- not the credibility
18 criteria, just the -- all your other statistical
19 comparisons?

20 Would it come out -- would that come out
21 better?

22 MR. WIDREVITZ: The short answer, there's
23 quite a lot of things in the public domain that have
24 done those. For example, ASTM has an adjunct out in
25 the public domain when they generated E900 that goes

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1 into a lot of statistical results that compare curves.

2 So, there's a fair amount of information
3 out there about that.

4 MEMBER RICCARDELLA: And does it come out
5 in general better that the -- did the statistical
6 tests turn out better with that then with --

7 MR. WIDREVITZ: Everything is better than
8 this Reg Guide.

9 MEMBER RICCARDELLA: Yeah.

10 MR. WIDREVITZ: All newer curves that I've
11 seen evaluated, and one would expect that.

12 MEMBER RICCARDELLA: Yeah.

13 MR. WIDREVITZ: But it's -- there's more
14 data. There's more advanced curve fits. There's more
15 information out there.

16 And so, that's -- you know, I don't want
17 to cast dispersions, because I think they did a
18 wonderful job with what they had.

19 MEMBER RICCARDELLA: Yeah.

20 MR. WIDREVITZ: But at the same time,
21 you're taking a snapshot in time.

22 (Off-microphone comment.)

23 MR. WIDREVITZ: Right. And that's just
24 not part of this technical assessment. That's more of
25 a next steps in terms of internal work.

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1 Which we're not discussing today. Sorry,
2 I know it's an unsatisfying answer, but.

3 MEMBER RICCARDELLA: No, it's just, you
4 know, we're moving at our typical regulatory snail's
5 pace. It will take us five years to get anything
6 done.

7 MR. MITCHELL: We are very much hoping to
8 do way better than that.

9 MEMBER MARCH-LEUBA: It's in the record.
10 We'll hold you to it.

11 (Laughter.)

12 MR. WIDREVITZ: And that's, you know, part
13 of that question is, if it takes the NRC five years,
14 what calendar year are you going to really want it
15 done?

16 I mean, and that's -- that's part of why
17 -- where is it? There we go. Why you make plots like
18 this. Because you want to -- you really want to
19 understand where you are.

20 And this is, beginning of the answer to
21 some of those questions.

22 MEMBER KIRCHNER: What's the answer? How
23 many years do you have?

24 MR. WIDREVITZ: So, based on this --

25 MEMBER KIRCHNER: Based on your curves,

1 yeah.

2 MR. WIDREVITZ: Based on these curves,
3 assuming it takes the NRC five years to do anything,
4 we should have started last year. Give or take,
5 depending on where you want to -- where you begin to
6 get excited about the inaccuracy of your base metals.

7 And there, you know, I have a lot of
8 qualifiers in there because as Dr. Riccardella
9 mentioned, when you start looking at it, you know,
10 what is significant?

11 Are these materials in front? Are these
12 the limiting materials? If they're not, then you
13 might have more time.

14 Will they become the limiting materials?
15 Then you might have less time. So there's a lot of
16 subtleties to answering that.

17 But I'd say based on this plot, which we
18 know is a little bit ahead of truth, no. Now is when
19 we want to start.

20 And that's me, Dan Widrevitz. Not
21 speaking for literally everyone. But there is a
22 working group, so.

23 I think we've beat this particular horse.

24 MR. IYENGAR: This is Raj Iyengar. I just
25 wanted to -- I don't think it's going to take five

1 years.

2 But, I think that's a number thrown at all
3 of us. But it could be done faster. But we haven't
4 fully, like Dan was saying, we haven't fully gone to
5 the next steps yet to evaluate it.

6 To tailor the points, and the high points.
7 To look if there's any mechanistic basis that would
8 give us different opinions.

9 So, we haven't done that assessment yet.
10 We are in the throes of it. But we wanted to provide
11 this assessment to you at this time so that we can
12 understand that move next.

13 So it's certainly not five years. We do
14 things faster.

15 MEMBER MARCH-LEUBA: Well, but going back
16 to what Peter was saying, if we knew what the impact
17 of each of these -- there are errors.

18 MR. IYENGAR: Right.

19 MEMBER MARCH-LEUBA: Or inaccuracies.

20 MR. IYENGAR: Right, right.

21 MEMBER MARCH-LEUBA: If we know what the
22 impact is, we can tell you, Dan, stop everything else
23 you're doing and go to work now.

24 MR. IYENGAR: That's right. Exactly.

25 MEMBER MARCH-LEUBA: Or, oh, whenever you

1 have time, work on it.

2 MR. IYENGAR: Right.

3 MEMBER MARCH-LEUBA: That would be a first
4 step.

5 MR. IYENGAR: Right.

6 CHAIR BALLINGER: For me that's the key
7 question. Which I don't have -- which this doesn't
8 answer.

9 MEMBER MARCH-LEUBA: The question is, do
10 we need to tell your boss that you cannot work on
11 anything else?

12 MR. WIDREVITZ: I understand the question.
13 I cannot answer with more information.

14 MEMBER MARCH-LEUBA: So that's the -- in
15 my opinion, in our opinion that's the first step, is
16 this here.

17 MR. WIDREVITZ: And I -- and that's really
18 again, I -- in terms of the information we're
19 providing, this is a little conservative, but this is
20 really trying to answer your question.

21 And you can decide for yourself, three,
22 six, eight, take a look at the data. Take a look at
23 the results.

24 MEMBER MARCH-LEUBA: But when I look from
25 -- when I look at that scale in a little tiniest time,

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1 20 feet away, I'm not aware of 6 to the 19.

2 I mean, I have to look very carefully to
3 see the deviation. Now, 10 to the 20, yeah.

4 CHAIR BALLINGER: I think he -- Pete was
5 saying, he doesn't care about the -- going all the way
6 to the pressure temperature curve.

7 I'd like to see an example of the effect
8 on the pressure temperature curve for a plant that's,
9 you know, likely to be in this situation. For say
10 between -- after license renewal for example.

11 MR. WIDREVITZ: Two observations. The
12 first is, 6 and 10/19 is when the mean of the
13 predictions hits, give or take.

14 The two sigma lower bound of the current
15 prediction. Personally, that's bad. From every rule
16 of thumb that's not where you want to be.

17 MEMBER RICCARDELLA: For the base metal?

18 MR. WIDREVITZ: For the base metal.
19 Right.

20 MEMBER RICCARDELLA: In general, will
21 metals govern it?

22 UNKNOWN: Mostly, no.

23 MEMBER RICCARDELLA: Hum?

24 UNKNOWN: No.

25 MEMBER MARCH-LEUBA: Okay. Now, to make

1 comments you need to go to the microphone and say your
2 name. If you want to be on the record.

3 MR. KIRK: Mark Kirk, CRIEPI. No. About
4 50 percent, and the NRC staff can say this too. I
5 believe it's about 50/50 weld versus plant plate limit
6 for iron plate.

7 MEMBER RICCARDELLA: For heat up and cool
8 down though.

9 CHAIR BALLINGER: For heat up/cool down?

10 MEMBER RICCARDELLA: Yeah.

11 CHAIR BALLINGER: I didn't know that.

12 MR. KIRK: So the, yeah, the base metal is
13 not significant. The base metal will have smaller
14 shifts of course, but in a low shift plant, base metal
15 can be limited.

16 MR. WIDREVITZ: Well, and that's again,
17 for new reactors, those are the only plants I have,
18 you know, are low shift.

19 And they've moved all their welds out of
20 the belt line, you know. But, again, their shift is
21 going to be low.

22 So, it's --

23 CHAIR BALLINGER: Yeah. They're all low
24 copper.

25 MR. WIDREVITZ: Right. The second part of

1 the question is, is yeah, I would have liked to have
2 brought a bit more.

3 You know, if you look at some pressure
4 temperature limit methodologies they take -- they just
5 take in RTndt as sort of a linear term.

6 So there's, you know, some -- depending on
7 what plant methodology they use to get different
8 outcomes in terms of how sensitive they are and how
9 they work and manipulate it with it.

10 So, it gets too complex very quickly. And
11 I understand the interest. And I think that's
12 something that's certainly worth thinking about in
13 terms of next steps, what questions we need to answer
14 to understand things.

15 MR. MITCHELL: Yeah. And I'll just chime
16 in, Dan, along with you. And say that, I mean, I
17 think the step that we're at is, discovering or
18 confirming as we're going through and looking at how
19 the model performs.

20 That we have reason, we have -- we think
21 we have a reason to go to the next step of
22 investigating exactly these questions. What is the
23 significance of what we are discovering here about
24 where Reg Guide 1.99, Rev. 2 may not perform
25 appropriately? Or may not be as accurate as we would

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1 like?

2 Going forward as we hopefully proceed down
3 that path, if we discover anything that suggests that
4 it is a very significant -- that we are seeing
5 significant from a regulatory and safety impact
6 deviation, then we will have to consider what is the
7 timing, appropriate timing of a regulatory step? When
8 we get that information.

9 So, it is -- we understand it's
10 dissatisfying right now. But we're just find -- what
11 we're finding evidence of right now, I think, is that
12 we need to ask that question.

13 And we need to continue to investigate
14 that question of, what is the significance of how the
15 Reg Guide is performing?

16 Now let's go find out what you're -- what
17 it means. And then decide how to react at that point.

18 MR. ALLEY: So, to put it another way, the
19 fundamental data analysis that starts the process
20 appears to have that high fluence, some issues worth
21 of consideration.

22 We now have to get to what's the
23 implication to the fleet? Do we have an adequate
24 protection issue?

25 And so, the Reg Guide review was supposed

1 to get to the question of, is there enough of a
2 difference between the knowledge that existed at the
3 time that the Reg Guide was created and now to make it
4 worth considering revising the Reg Guide?

5 And so you're getting the answer to the
6 question of, is it worthy at this point in time to
7 consider revising the Reg Guide?

8 MEMBER RICCARDELLA: Which and the answer
9 to that is yes.

10 MR. ALLEY: Well, we'll let Dan get to his
11 conclusion in a few moments.

12 CHAIR BALLINGER: But you've gone and used
13 the AP words, adequate protection.

14 MEMBER RICCARDELLA: Well --

15 MR. ALLEY: In today's world, given that
16 we have Commission direction, --

17 CHAIR BALLINGER: That's right.

18 MR. ALLEY: Relatively new on forward
19 fits, back fits, --

20 CHAIR BALLINGER: Yep.

21 MR. ALLEY: Adequate protection becomes a
22 key piece in all of our deliberations going forward.
23 And we will proceed in accordance with those
24 directions from the Commission regarding back fit,
25 forward fit, adequate protection, as we proceed

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1 through our assessments as to where do we go from when
2 Dan stops talking to where we have some sort of a
3 final disposition?

4 MR. WIDREVITZ: Okay. So, critical
5 consequence. For the benefit of fitting prediction
6 service data is nullified by credibility criteria that
7 rejected and did not conform in the shape function of
8 Reg Guide 1.99.

9 And just sort of what does that mean in
10 practice? High fluence and low copper data are not
11 expected to form to the shape function of Reg Guide
12 1.99.

13 So, as a new reactor person, that's kind
14 of an accuracy that I would tend to focus on. Other
15 then the fact that they reject data more strongly as
16 you have more data, seems like an unfortunate
17 characteristic as well.

18 If by chance your credibility criteria,
19 deemed re-creditable data is being creditable, then
20 you're allowed to reduce your margin term.

21 Again, we couldn't find any apparent basis
22 for doing this in the background material. Obviously
23 it doesn't mean there wasn't any. But we didn't find
24 it.

25 But it does appear to work with the data.

1 Data that had good scatteraker (phonetic)
2 characteristics that are likely to pass through
3 credibility criteria, also tend to have better
4 statistical properties.

5 So, you loosen your margin based on
6 uncertainties seems to be appropriate. And you see
7 that on these plots where we've plotted sort of
8 standard deviation by scatter, where each -- each gray
9 dot is a material set of data.

10 And that orange line is what margin you
11 would have based on applying either the margin credit
12 with credibility criteria single outlier test, or just
13 the generic Reg Guide 1.99 credit for the base and all
14 materials.

15 In terms of the attenuation formula, the
16 attenuation formula that is given in the Reg Guide
17 matches very well to modern results. The critical
18 factor being here is when the Reg Guide was written,
19 your materials of interest were all essentially
20 horizontally adjacent to the fuel.

21 And as we've continued to age, you've seen
22 areas of the reactor where the fluence of interest
23 creep up above and below the fuel. And this form of
24 interest doesn't work there.

25 That's not a new result. And it's just,

1 there's no -- there's no caution in the Reg Guide
2 towards that.

3 So, that's sort of a limitations
4 deficiency. But technologically it works fine for
5 what it was designed to do.

6 Here we have a couple of plots from a
7 report where essentially your left had is what I call
8 the geometric belt line. It's the belt line
9 horizontally adjacent to fuel. It looks good.

10 When you look at a point above the core,
11 you're not getting an accurate result. And that's
12 well acknowledged. There's plenty of work going on
13 about that, this Reg Guide sheet.

14 MEMBER RICCARDELLA: It doesn't attenuate
15 as fast? Is that the --

16 MR. WIDREVITZ: Yeah. Yeah, your --

17 MEMBER RICCARDELLA: The dash curve is?

18 MR. WIDREVITZ: The dash curve is a, I
19 believe, if my recollection is correct, it is a three
20 dimensional neutron code result. I could be off a
21 little bit.

22 Whereas the line is -- is your Reg Guide
23 result.

24 MEMBER RICCARDELLA: Okay.

25 MR. WIDREVITZ: Obviously other members of

1 the NRC are looking into this with great interest.
2 So, we'll see where that goes.

3 Common additions, I already talked a
4 little bit about the degree for degree, which is an
5 attempt to bring some temperature information in.

6 Another common addition is what we've come
7 to call sister plant. Essentially when you've got
8 heat and action data in other capsules, and you need
9 more data, you try to adjust it towards the
10 circumstances of a particular vessel.

11 And then run it through your credibility
12 criteria or other methods. What we find is, is that
13 when you do this you tend to get standard deviations
14 that are a little bit higher, which shouldn't be a
15 huge surprise since you're doing a data adjustment.

16 In addition, as I've discussed, there's a
17 whole lot of residuals in the Reg Guide. So, maybe
18 some of this increase in standard deviation is coming
19 from just the accuracy to the adjustment.

20 Didn't get into it too deeply. But the
21 short answer is, is it's not entirely different from
22 using plant specific data. Not critically different.

23 But obviously, not as sophisticated as
24 some of the other portions of the Reg Guide. And its
25 performance is a little bit worse than just using

1 direct plant specific data.

2 So, conclusions, primary deficiency is the
3 greatest sort of inaccuracies that get people
4 interested. The high fluence RTndt predictions,
5 particularly the base metals, the credibility criteria
6 performance or even the part of base credibility
7 criteria.

8 The embrittlement trend curve shape
9 function, additional deficiencies, many gaps were
10 filled by a presentation, which currently lives in
11 Adams.

12 It's the presentation actually in a New
13 Reg literally echoed, we had a presentation, here's
14 what it said. Statistical treatments like the
15 standard deviation also could use a little help.

16 So, I know there's a little bit more in
17 the assessment itself. But I think these are the
18 highlights.

19 Deficiencies exist in every aspect of the
20 Reg Guide. From the technological from an accuracy
21 standpoint, this is true.

22 I'm not talking about significance. I'm
23 not talking as in -- as an NRC program office
24 employee. I'm talking as a research employee who is
25 really looking at the accuracy more than the

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1 significance.

2 And I believe from these results
3 deficiencies become concerning for high fluence PWRs
4 beginning in the late 2020s. Somewhere in there.

5 In terms of next steps. Well, I think you
6 can read some -- read a little bit into the fact that
7 we've convened a working group to look into exactly a
8 lot of the questions that we've been discussing today
9 in terms of licensing basis impacts and potential
10 solutions.

11 Obviously the science community and the
12 industry community and the standards community have
13 not stood still for 30 years. So there's a great deal
14 out there.

15 We're not, you know, this isn't a blank
16 page investigation. But licensing basis are a very
17 unique entity. It's not necessarily the same as best
18 estimates, complexity, et cetera.

19 CHAIR BALLINGER: Now, with respect to the
20 working group, and that's all we know. What's their
21 schedule?

22 What's, you know, what's their charge? Is
23 there a charge?

24 MR. WIDREVITZ: I defer to my betters to
25 answer that question.

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1 CHAIR BALLINGER: I mean, it's a kind of
2 a pregnant statement, but.

3 MR. ALLEY: So, we have received -- this
4 is Dave Alley, NRR. We have received from research
5 the report that Dan is providing the information to
6 you on today.

7 We have looked at the report, and we have
8 determined that there is sufficient merit to go
9 forward in considering a revision to the Reg Guide.

10 The -- we're trying to work on a very
11 aggressive time table to make that initial
12 determination. Which is probably better said weeks
13 rather than months.

14 CHAIR BALLINGER: Okay.

15 MR. ALLEY: At this point. And that will
16 be to make some assessments with respect to what does
17 this mean as far as adequate protection goes?

18 And I have a couple of slides that we'll
19 talk about later.

20 CHAIR BALLINGER: I was about to say,
21 we're into your presentation now, is what you're
22 saying?

23 MR. ALLEY: We almost are. We almost are.
24 Let me let Dan finish --

25 CHAIR BALLINGER: Okay.

1 MR. ALLEY: Before I steal any more of my
2 own thunder shall we say.

3 CHAIR BALLINGER: I don't see any more
4 slides.

5 MR. WIDREVITZ: No. This is it. So, if
6 you have questions for me.

7 CHAIR BALLINGER: That's it. I was about
8 to say.

9 (Laughter.)

10 MEMBER KIRCHNER: Okay. Dan, just a point
11 of clarification. Slide 24, so that's -- the second
12 curve, the second thought on the right.

13 The DPA, that was done with MCNP? Or some
14 other method?

15 MR. WIDREVITZ: Honestly, I don't recall
16 the details of that report.

17 CHAIR BALLINGER: It's just a reflection
18 of the fact that when you go straight through the
19 vessel, you get a different kind of attenuate. You
20 get streaming up the vessel.

21 MEMBER KIRCHNER: Yeah. No, I understand
22 that.

23 CHAIR BALLINGER: Instead of the flux.
24 The flux as to energy distribution changes that.

25 MEMBER KIRCHNER: No. I was just curious

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1 how they created the --

2 MR. WIDREVITZ: Well, I don't think they
3 even -- I don't think this is even high enough to
4 worry about streaming yet.

5 CHAIR BALLINGER: Okay.

6 MEMBER KIRCHNER: No. This is just the
7 upper portion.

8 MR. WIDREVITZ: This is above the fuel,
9 but not -- I mean like --

10 MEMBER KIRCHNER: Yeah. The upper part.

11 MR. WIDREVITZ: I mean, like, yeah. I
12 don't know exactly how much. But a --

13 MEMBER KIRCHNER: Three dimensional --

14 MR. WIDREVITZ: Yeah.

15 MEMBER KIRCHNER: It's a three dimensional
16 effect. Yeah.

17 (Simultaneous speaking.)

18 MR. WIDREVITZ: Yeah.

19 MEMBER KIRCHNER: And so what you're
20 saying is that some higher order method, whether it's
21 MCNP or whatever, --

22 MR. WIDREVITZ: Yeah.

23 MEMBER KIRCHNER: Gave you the dash curve.
24 But then this is the --

25 MR. WIDREVITZ: I believe all of that.

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1 MEMBER KIRCHNER: This curve is what's in
2 the Reg Guide.

3 MR. WIDREVITZ: I believe that's correct.

4 MEMBER KIRCHNER: Yeah. So that's non-
5 conservative.

6 MR. WIDREVITZ: Which is wrong. It
7 doesn't apply.

8 MEMBER KIRCHNER: Just wrong, yeah.

9 MEMBER RICCARDELLA: Except for the left-
10 hand plot is pretty good. It's right straight up
11 above.

12 MEMBER KIRCHNER: No. No, I -- this is
13 what you go by.

14 MR. WIDREVITZ: Yeah. And if you go back
15 into the Reg analysis and everything, they're very
16 clear about what that curve is good at. They just
17 were not concerned about these other areas.

18 So they didn't specify in the Reg Guide
19 text, so.

20 MEMBER REMPE: So, with respect to
21 potential solutions, somewhere in this presentation I
22 recall you making a statement offhand about anything
23 is better than this Reg Guide.

24 And do you want to elaborate more of what
25 you're thinking about with potential solutions?

1 MR. WIDREVITZ: Well, I think a really
2 interesting place to start is to -- the ASTM
3 background information, 3900 had a huge amount of
4 discussion about different curves and history.

5 And I think if you're feeling curious,
6 there's some really good information I don't have to
7 defend in there, --

8 MEMBER REMPE: Um-hum.

9 MR. WIDREVITZ: In terms of the NRC
10 staff's position and our findings. And you can draw
11 your own conclusions based on the author's.

12 MEMBER REMPE: Okay. Thank you.

13 CHAIR BALLINGER: Are we into the Alley?

14 MEMBER MARCH-LEUBA: Can I make one point

15 --

16 CHAIR BALLINGER: Yes, now.

17 MEMBER MARCH-LEUBA: Before we go to
18 Alley?

19 CHAIR BALLINGER: Yeah. You go ahead.
20 Take your time.

21 MEMBER MARCH-LEUBA: It's a size, but I
22 see you're not going to rush into it. No matter how
23 much we prod you.

24 But, yesterday we had a review of
25 historical facts correlation. And NRR has issued a

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1 knowledge management NUREG, KM0013.

2 Which it's under part review now, which
3 deals with data driven models. How did you review and
4 use them.

5 So, since this Reg Guide is going to be a
6 data driven model, I would urge you to at least read
7 it or consult with the CHR guys.

8 Because we were very impressed with the
9 approach they used for reviewing the CPR original.
10 And they produced a NUREG.

11 And this is how we're going to review
12 particular -- that doesn't even model for now on. And
13 this is how we were expecting to meet them.

14 So, it will give you some ideas of what to
15 look for. It's not that long. But it has 25 items
16 that you're supposed to follow. Check marks. It's
17 really good. KM0013.

18 MR. IYENGAR: Yeah. This is Raj Iyengar.
19 Thanks Dan for a good presentation. I know you, I
20 think you stirred a lot of questions with the data
21 that you've provided. And NRR and NRO management
22 weighed in on that.

23 I wanted to emphasize to you that as
24 stated in one of the conclusion slides that what
25 they're looking at would be a concern in potentially

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1 the late 2020.

2 So, right now we're bringing it up way
3 ahead of time of time so that it's not something that,
4 you know, it's an immediate concern tomorrow.

5 So, we do have time. But we are also
6 working to looking at the alternatives like Dave Alley
7 was saying.

8 We have some ideas. And we have to flush
9 out many different things, looking at licensing basis
10 and all that stuff.

11 So, we are in, not in a snail speed, if
12 that's what I heard. We are speeders in a different
13 mode. We are bringing way ahead proactively, bringing
14 all these issues up front.

15 So, I just wanted to emphasize that.
16 Thank you.

17 CHAIR BALLINGER: Now it may -- it --
18 2020, late 2020, or the late 2020s may not be an
19 immediate concern.

20 But if you're sitting with a plant and
21 you're thinking about lice -- or subsequent license
22 renewal, and you've got financial considerations,
23 that's tomorrow.

24 MEMBER RICCARDELLA: Well, but also I
25 suggest that that estimate of the late 2020s was

1 brought with a pretty broad paintbrush.

2 And that in fact, you know, if you -- when
3 your working group gets into it, you might find that
4 there's a plant or two out there that it's much more
5 immediate than that.

6 MR. ALLEY: Something clearly we'll
7 consider. And we certainly understand this concept
8 that ten years from now is the planning horizon, or
9 maybe even well into the planning horizon for certain
10 plants for certain actions.

11 So, that's part of what I'm going to tell
12 you here. If we go to the next slide, we might as
13 well get started.

14 So, as I think we've been saying that NRR,
15 and I should, I was remiss as I was writing these
16 slides. NRO and NRR are reviewing the implications of
17 the research findings that Dan has just presented.

18 And certainly if we get to a spot where we
19 have an adequate protection issue, we will absolutely
20 address that. And we will absolutely address that in
21 a timely fashion.

22 Fundamentally, it's not clear to us at
23 this point that all plants will fall into that
24 category. As a matter of fact, many, many may not.

25 In many cases the existing Reg Guide as

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1 far as adequate protection issues, may prove to be
2 just fine well into the future.

3 As we saw in the -- in some of the plots
4 that Dan presented, it's not until you get to high
5 fluence that we start to see substantial deviations
6 from the Reg Guide predictions in one particular
7 direction or another.

8 Scattered, yes. But as we start to get
9 out into higher fluences, we start to see some sort of
10 systematic deviations. And those could conceivably
11 get to be adequate protection issues at some point in
12 the future.

13 So, the concept adequate protection,
14 clearly something that the Commission wants us to
15 address. They provided guidance to us concerning
16 forward fits and back fits that we will be following
17 as we consider where to go and how to deal with those
18 issues.

19 They've also provided guidance that says
20 that if we don't have -- don't meet certain standards
21 such as adequate protection, that regulatory burden
22 should be avoided where it's unnecessary.

23 And we will be considering that certainly.
24 There are things that we may get into as was
25 mentioned. There's a relationship between what we're

1 doing with this Reg Guide and potentially 50.61(a).
2 Potentially Appendix H. Potentially Appendix G.

3 So, we're not going to say at the present
4 time that our efforts are strictly related to this Reg
5 Guide. It could spill over into a rule making
6 activity.

7 We're not saying that it will. But we're
8 clearly not saying that it won't at this point.

9 So the message here is, we're looking.
10 We're trying to figure out where we're headed as far
11 as adequate protection.

12 And we're going to make sure as we proceed
13 forward that we're not imposing any unnecessary
14 regulatory burden. If we can shift to the next slide.

15 As Dan has pointed out, we don't have an
16 immediate safety concern at the moment. Based on what
17 we know now, as I was saying, the plants, the issue
18 seems to be most -- the adequate protection issue
19 seems to be most at higher fluence plants.

20 The plants are not yet there. The plants
21 won't be there for a few years. On the other hand, as
22 you have been inquiring of us, is it time to do
23 something?

24 And the answer is, it's time at this point
25 in time to consider what the adequate protection

1 issues maybe here. To figure out to whom any changes
2 that we would make should be applied.

3 To minimize the efforts, or the effects on
4 those that are not affected, shall we say. And the
5 time to do it is now, or as quickly as we can possibly
6 do it, to provide regulatory reliability, regulatory
7 stability to those plants who either will or will not
8 have to adjust how they operate at some future date.

9 So, at this point we're not prepared to
10 tell you specifically, this is going, this effort is
11 going to apply to six plants, but not seven. We're
12 not going to tell you at this point that it's going to
13 be applicable in 2022.

14 I'm making all this stuff up as I go
15 along. Because we just don't know precisely where we
16 will wind up.

17 We do know that the technological
18 assessment points to the concept that it is time to do
19 a regulatory and safety assessment and adjustment
20 where needed.

21 Do you want to add anything to that?

22 MR. MITCHELL: Just I'd add one thing to
23 connect your final bullet Dave, to what Dr. Ballinger,
24 a point you made just a few moments ago.

25 In that in terms of regulatory

1 reliability, certainly there would be a factor, right.
2 If we were to determine that going to new models were
3 to, but we would need to go to the new models because
4 there could be questions about the protection.

5 Plants would need to potentially make
6 decisions related to, do they want to impose a
7 different core design to suppress fluence in a
8 particular region by using absorber bundles.

9 So, knowing sooner that there may be an
10 issue ten years from now, would be, I think,
11 regulatorily appropriate to communicate that.

12 So that plants could take action
13 potentially today that would avoid that difficulty
14 down the line, if there were ways to manipulate their
15 core design or other actions, which could alleviate
16 that issue, or step it back from coming up in ten
17 years. It may push it out to 20 years in the future,
18 et cetera.

19 So, knowing sooner is certainly a good
20 thing, I think, from everybody's perspective.

21 CHAIR BALLINGER: And all those actions
22 would all be negative and involve costs. Lots of
23 costs.

24 And you're familiar, I'm sure, with
25 Loviisa Unit Number One?

1 MR. MITCHELL: I probably should be.

2 CHAIR BALLINGER: They made the vessel out
3 of basically car parts.

4 MR. MITCHELL: Hum.

5 CHAIR BALLINGER: And they had a 270
6 Fahrenheit, I think, degree increase in NTD in one
7 cycle. And they had to de-fuel the outer ring of the
8 reactor.

9 And they converted a 700 megawatt reactor
10 into a 400 megawatt reactor.

11 MR. MITCHELL: Wow.

12 CHAIR BALLINGER: So, interesting reading.

13 MR. MITCHELL: That's a -- wow, that's an
14 interesting story I hadn't read up on.

15 (Laughter.)

16 CHAIR BALLINGER: So back to the serious
17 part.

18 MR. MITCHELL: Yes.

19 CHAIR BALLINGER: The working group.

20 MR. MITCHELL: Yes.

21 CHAIR BALLINGER: Does it have a charter?
22 Can we get it? Does it meet? Can we rely on you guys
23 to come and brief us on a regular basis on this?

24 Because I -- now in my personal opinion,
25 I think it's an important issue for us to be up to

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1 speed on, and not behind the curve.

2 MR. ALLEY: Okay. So the answers to some
3 of your questions are, the working group is meeting on
4 about a weekly or a biweekly basis.

5 They have a report to us biweekly, every
6 two weeks. Twice -- semi --

7 MR. IYENGAR: No. It's twice a week.

8 MR. ALLEY: Semi-weekly basis.

9 MR. IYENGAR: Twice a week. And we have
10 not written a charter yet. But, I did want to answer
11 -- I'm sorry to interrupt Dave Alley.

12 We actually had wanted to have a full
13 committee briefing done. And after that we were going
14 to come back to you with a working group
15 recommendation.

16 But the full committee briefing has been
17 postponed, as I understand from Christopher Brown,
18 until November.

19 CHAIR BALLINGER: Okay. Now I understand
20 why. Yeah. I understand why that change was made.
21 I wanted to be here, and I wasn't going to be here.

22 MR. IYENGAR: Yeah.

23 CHAIR BALLINGER: So, but that's separate
24 then the working group issue.

25 MR. IYENGAR: It is -- it is separate but

1 tied though. Because we wanted to get, as I told you
2 in our meeting, we would like actually a letter from
3 ACRS.

4 CHAIR BALLINGER: Yep.

5 MR. IYENGAR: Which will actually help us.
6 And we also wanted to engage external stakeholders and
7 the public about the working group findings and
8 recommendations.

9 That's something we owe to the public, for
10 transparency. So, we want to do all that. And having
11 something from you would enable those things.

12 But we could actually, because of this
13 postponement, we could consider doing that a little
14 bit sooner. We don't have to wait until November.

15 MR. ALLEY: So anyway, thanks Raj, because
16 I was going to mention that we were coming back to the
17 full Committee in a month or two. And so if that's
18 not going to happen, --

19 MR. IYENGAR: It's November.

20 MR. ALLEY: Events have overtaken my
21 knowledge at this point. So, we are -- the working
22 group is very active at this point.

23 As is the management oversight of that
24 group. Trying to ensure that we keep a forward
25 progress at the most rapid rate that we possibly can.

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1 So, we're trying to make absolutely sure
2 that we don't get into a tailspin on this one where
3 we're not making progress.

4 MEMBER MARCH-LEUBA: Yeah. And that's
5 perfect. I tend to oversimplify things. And that's
6 why I get in trouble all the time.

7 But, Walt was saying the same thing this
8 morning when we were talking. We overkill things. I
9 don't know what the working group is doing.

10 I have no idea where the adequate
11 protection or regulatory burden placed into this
12 problem. We developed RG 1.99 is nothing short of but
13 a sophisticated correlation where you input the number
14 of data points, and it tells you what the output is.

15 It is a correlation. We have run sort of
16 statistic, which was still over 177 points. We now
17 have two thousands. We've run sort of statistical
18 tests and we know the correlation is wrong. Okay.

19 So stop doing, going in circles. Feed a
20 better correlation and publish it. And the problem is
21 solved.

22 And there's nothing to do with adequate
23 protection. There's nothing to do with regulatory
24 burden.

25 Everybody just uses the correct

1 correlation from now on. What's wrong with that?
2 What are you doing in this working group?

3 MR. ALLEY: Okay. So, the working group
4 is considering the implications of what happens to --

5 MEMBER MARCH-LEUBA: The correlation is
6 inaccurate. We've seen it in several standard
7 deviations.

8 So, I mean, the statistical test comes out
9 like 20. Those are incorrect. Feed a new line and
10 use it.

11 MR. ALLEY: Okay.

12 MEMBER MARCH-LEUBA: I mean, and be done
13 in two months.

14 MR. ALLEY: And -- and --

15 MEMBER MARCH-LEUBA: You can be done by
16 November.

17 MR. ALLEY: I'm not -- well, -- I'm not
18 going to say that we'll be done by November, because
19 there's public comments and there's publishing. And
20 there's all of these other things that go along --

21 MEMBER MARCH-LEUBA: You can have the line
22 fitting by November. You can have the line fitted by
23 Sunday.

24 MR. ALLEY: Well, and one of my objectives
25 is to make sure, as I said, that we try to do this in

1 weeks, and not months, and certainly not years, from
2 the technical standpoint.

3 The piece that we have to be careful
4 about, all right, is the Reg Guide at the bottom says,
5 if you follow this, we the NRC will accept it as in
6 licensing actions. And --

7 MEMBER MARCH-LEUBA: Yeah. And if Part 21
8 will apply to you, you will go to jail. Because you
9 now know that that recommendation that you're
10 producing using the part, the current correlation, is
11 inaccurate.

12 And so -- so establish -- a proper
13 suggestion to bring it back into compliance.

14 MR. ALLEY: All right. So you made an
15 assessment there that -- that I'm not going too quite
16 accept in its entirety.

17 From a regulatory perspective, as Dan
18 pointed out, we can have better correlations. And at
19 high fluence, there appears to be a non-conservative
20 deviation.

21 But, at the lower fluence plants, there is
22 nothing, in my personal eyes, that at the moment would
23 cause me to be able to say that plants that are using
24 the current correlation at lower fluences, are unsafe.

25 And therefore --

1 MEMBER MARCH-LEUBA: And there's nothing
2 wrong with that.

3 MR. ALLEY: And therefore, I have to be
4 careful as I write a new Reg Guide, to say anything
5 about, if you follow this, we will accept it. Or if
6 you don't follow this, we will take -- have to take
7 more time looking at it.

8 So, while -- while you're quite correct in
9 saying it's a correlation, and we have potentially,
10 potentially better correlations, it's the, and use it
11 part, that goes from where Dan is to where I am, as
12 far as what is the regulatory -- what is the
13 regulatory burden or the regulatory advantage relative
14 to adequate protection of making a change?

15 MEMBER RICCARDELLA: Could I talk?

16 MR. ALLEY: Go for it.

17 MEMBER RICCARDELLA: Given that we have to
18 have this postponement of the full committee meeting,
19 and the letter, because our esteemed Chairman is going
20 to be out of the country in October, and the speed
21 with which you appear to be going with the working
22 group, would it be productive to have another
23 subcommittee meeting before November, where we get to
24 see some of the results of this working group effort?

25 And then we can build that into our letter

1 as well.

2 MEMBER MARCH-LEUBA: Well, talk to our
3 scheduling people. We're very -- I mean, we're
4 completely full in November subcommittee wise.

5 CHAIR BALLINGER: No. But we're scheduled
6 for November.

7 MEMBER MARCH-LEUBA: Not in the full
8 committee.

9 MEMBER RICCARDELLA: November full
10 committee.

11 MEMBER MARCH-LEUBA: To have a
12 subcommittee.

13 MEMBER RICCARDELLA: No, it would be -- no
14 unfortunately we don't have October subcommittee.

15 MEMBER REMPE: You have to. We still have
16 that.

17 (Simultaneous speaking.)

18 CHAIR BALLINGER: That's what's
19 complicating life.

20 MEMBER RICCARDELLA: We're working towards
21 transforming ourselves a little bit here too.

22 MR. ALLEY: Okay. So, I guess --

23 MR. IYENGAR: I just want to say, you
24 know, I want to tell you that we -- the working group
25 is doing many things.

1 One is to verify all the data. Because if
2 you go to slide 13 that the data is, needs to be
3 rerun. The licensing basis document, we've got to do
4 that. We're doing it very fast.

5 We could engage with you. Research is
6 leading the working group. And we do have
7 representatives from NRR and NRO.

8 We are open to coming to the subcommittee
9 prior to November 3. And if we have in the next
10 several weeks, we should be able to tell you where we
11 are in the next several weeks to be able to come and
12 brief you if needed.

13 CHAIR BALLINGER: Oh.

14 MR. IYENGAR: Yes. I we --

15 CHAIR BALLINGER: I'm looking at, and I'm
16 going to walk way out on a plank here, and he's
17 shaking his head already.

18 Subcommittee in September? Monday morning
19 is open.

20 MR. BROWN: So that's a problem. We've
21 got --

22 CHAIR BALLINGER: Monday morning is open
23 too.

24 MR. IYENGAR: And I -- what date is that?
25 It might be too soon in September.

1 CHAIR BALLINGER: The 16th.

2 MEMBER MARCH-LEUBA: That might be too
3 soon.

4 CHAIR BALLINGER: But the working group
5 issue, you're saying you're all over the working
6 group. And that you're meeting every other, every
7 couple of weeks.

8 That would be two cycles between now and
9 September's subcommittee.

10 MR. BROWN: Okay. So, I could work with
11 Raj. And we can see about that.

12 MR. IYENGAR: Yeah. And I also --

13 MR. RICCARDELLA: What about October's
14 full committee?

15 MR. IYENGAR: And I also work with
16 management to find out, you know, if it's a good time.

17 CHAIR BALLINGER: Oh -- oh --

18 MEMBER RICCARDELLA: Wait, wait, wait.

19 CHAIR BALLINGER: Oh, October full
20 committee.

21 MEMBER RICCARDELLA: October full
22 committee, we --

23 CHAIR BALLINGER: We have Monday and
24 Tuesday.

25 MEMBER RICCARDELLA: Tuesday is empty.

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1 That would be October 1st. Yeah. October 1st could
2 -- do you think the working group could have a
3 meaningful presentation for us by say the afternoon of
4 October 1st?

5 MR. ALLEY: We can certainly put our heads
6 together and see where they are. We're going to get
7 at the branch chief management level, we're going to
8 get an update from them next week, I believe.

9 And once we see that, we can see where
10 we're likely to be. The other thing that we have to
11 make sure that we're in our process for Management
12 Directive 8.4, which is forward fits, back fits, to
13 make sure that we have communicated appropriately
14 through our management before we discuss with you
15 things that can be forward fits and back fits.

16 MS. LUND: Yeah. And this is Louise Lund.
17 And of course, I just arrived on the scene. But, I
18 will weigh in on this.

19 And I think that what would probably
20 provide more of a satisfying subcommittee discussion,
21 is not only having the working group come to whatever
22 resolution or proposals, recommendations, you know,
23 that they want us to consider.

24 But also have a little bit of time to
25 consider that through what Dave was talking about. To

1 get more of an idea where we seem to be actually
2 heading.

3 And it just seems like to me we're
4 already, you know, what is this, the 21st? The 22nd,
5 you know, of August, doing something in September
6 seems rather short to me to actually have the fulsome
7 dialog that we really need to have internally.

8 You know, I think that we're trying to
9 lean forward here, I think. And we're trying to
10 provide some information.

11 But this is the -- these are the obvious
12 questions that would come up as to, you know, what are
13 we going to do with what we know?

14 And I think that, you know, we owe a more,
15 you know, fulsome look at that part. Because
16 otherwise, we'll be having a lot of the same
17 discussion again.

18 You know, so that's why -- that's why I'm
19 a little concerned about just giving a month with
20 that.

21 MEMBER RICCARDELLA: Yeah. Clearly the
22 September is too short. But October?

23 MEMBER MARCH-LEUBA: Yeah. Can I ask a
24 question? Assuming you guys got what you are, I mean,
25 you wanted to have a full committee meeting October 2,

1 and a letter issued by us that week.

2 Can you tell me what you want in a letter
3 to say in will form? Because what I understand it
4 would say is, we have heard concerns from the staff
5 that Regulatory Guide 1.99 has inaccuracies.

6 And they are -- we have heard them trying
7 to improve those inaccuracies. And we support that.

8 Is that what you want the letter to say?

9 MR. ALLEY: That would be helpful.

10 MEMBER MARCH-LEUBA: We can write that
11 next week in September. Because we've already heard
12 it. And we support your efforts.

13 MR. ALLEY: Oh.

14 MEMBER MARCH-LEUBA: We don't need to wait
15 for that.

16 MR. ALLEY: All right.

17 MEMBER MARCH-LEUBA: What we want to see
18 is, what we are asking is what is the path forward
19 after that?

20 MR. ALLEY: And we certainly will endeavor
21 to provide you where we're going. But it was our
22 understanding that the full committee could issue a
23 letter.

24 MEMBER REMPE: That's absolutely correct.
25 But let's go back to what Raj said for a minute.

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1 Yeah, the after a second.

2 You said you had hoped we would have a
3 letter in October. We really can't do it in
4 September. We have a schedule that's full.

5 But if we had done that letter in October,
6 which is going to happen now in November, you had
7 said, or I think I heard you say that it would help
8 you to have something that would facilitate future
9 discussions with ACRS about this topic.

10 Is that what I think I heard you say Raj?

11 MR. IYENGAR: Not really future
12 discussions. But also we can engage external
13 stakeholders. Which we really want to, because that's
14 part of the things that we do normally with this.

15 So it would really speed this up for us.

16 MEMBER REMPE: So, could I suggest a
17 compromise of what I think I'm hearing from you? And
18 again, I appreciate, don't come and bring us piecemeal
19 stuff.

20 But, could you add a couple of slides that
21 talk about the charter that Ron was talking about for
22 the working group?

23 Some ideas about its structure. I still
24 don't know who all participates in it. How many
25 people from industry and all that.

1 And that would be enough to support the
2 letter that's planned for November. Instead of giving
3 us ad hoc stuff and adding another subcommittee
4 meeting and things like that.

5 Is that a compromise that's okay with
6 everybody concerned?

7 MR. IYENGAR: Yes. We could do that. Or
8 we could actually give you a kind of a one-pager of
9 what you're asking about.

10 Something which outlines what we're
11 applying to. We could do that as well.

12 MEMBER REMPE: Yeah. And then that would
13 be available for the full committee. And does that
14 kind of support what everybody wants to do that's a
15 meaningful compromise?

16 MEMBER MARCH-LEUBA: Yeah. In a sense,
17 full committees get an hour and a half. And I think
18 you can summarize what you've done.

19 MEMBER REMPE: Well, we've not yet heard
20 from EPRI. And some of the answers about why can't
21 you just do a correlation?

22 I think if you look at the slides that
23 EPRI's going to present, there's some industry
24 concern, in that -- about how this correlation gets
25 modified. And I think that that's the answer to your

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1 point.

2 And so --

3 MEMBER MARCH-LEUBA: Well, I'd like to
4 hear what the -- what the argument is to keep
5 something that is obviously statistically wrong.

6 MEMBER REMPE: Well, that's what they're
7 saying. Okay. But anyway, this -- Mr. Subcommittee
8 Chairman, it -- it's your turn.

9 CHAIR BALLINGER: Yeah. You know, if
10 we're into compromises, or swags, we could actually
11 have a subcommittee meeting on November 4. And a full
12 committee meeting on November 7 or 8.

13 And that would give you folks two months
14 at least to get this working group spun up. Or
15 whatever you're doing, and have some meat there.

16 That's a possibility.

17 MR. ALLEY: It would certainly -- it
18 certainly seems timing wise that the idea of coming to
19 you twice in one week, maybe excessive?

20 CHAIR BALLINGER: Well, but again, what
21 we're talking about is that we already have the
22 information, the boilerplate, the nuts and bolts part.

23 MR. ALLEY: Okay.

24 CHAIR BALLINGER: What we don't have, is
25 the working group issues and anything that happened.

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1 So, that would be an addition to the, what we already
2 have.

3 So it's not like a re -- a re -- it would
4 be new material. But it would be material that's very
5 easily incorporated into the letter, if we do, if we
6 do one.

7 MR. ALLEY: Okay.

8 CHAIR BALLINGER: And when you go to the
9 full committee, that's when you would present both
10 pieces.

11 MEMBER RICCARDELLA: A very abbreviated
12 version.

13 CHAIR BALLINGER: Yeah. A very
14 abbreviated version. So again, you're right, if we
15 were just to have a subcommittee meeting and a full
16 committee meeting where exactly the same thing
17 happened, that wouldn't make a lot of sense.

18 But in this particular case, you will have
19 had the advantage of several months of this working
20 group piece, --

21 MR. ALLEY: Um-hum.

22 CHAIR BALLINGER: That's non-technical.

23 MR. ALLEY: Okay.

24 CHAIR BALLINGER: All right? This is
25 management related stuff, I guess. I don't know.

1 MR. ALLEY: Well, there's both. Both
2 issues are being considered at the working group.
3 Both technical issues and regulatory implications
4 would have to go there.

5 CHAIR BALLINGER: Correct.

6 MR. ALLEY: As Dan mentioned, some of the
7 projections about how many plants and when they will
8 reach certain levels of fluence, are more
9 sophisticated if you actually go to the licensing
10 document.

11 CHAIR BALLINGER: Yeah.

12 MR. ALLEY: So, that's something that's
13 under consideration.

14 CHAIR BALLINGER: That package makes it --
15 it's a much more satisfactory and complete package for
16 a letter.

17 MR. ALLEY: Yes.

18 CHAIR BALLINGER: I mean, you know, I'm in
19 the --

20 MEMBER RICCARDELLA: If we were to write
21 a letter in November with only the information that we
22 have today on this assessment, it would be kind of
23 moot really, because --

24 MEMBER KIRCHNER: No. I disagree. We
25 would probably then start filling in the blanks along

1 the lines of questions we ask.

2 MEMBER RICCARDELLA: Yeah.

3 MEMBER KIRCHNER: And we would not be as
4 informed as we could be in doing so. We would --

5 MEMBER RICCARDELLA: Right. Right.

6 MR. ALLEY: Okay. So, with respect to
7 dates, well, with respect to the concept of, should we
8 be coming back to you and speaking with you to provide
9 additional information to make your letter to us
10 better and more useful, I'm going to fully agree with
11 that concept.

12 When we get to timing, given that research
13 is running the group, and is in charge of the timing
14 and the organization, I'm going to refer to Raj, or
15 defer to Raj at this point as to make the
16 arrangements.

17 MR. IYENGAR: So, I think Rob is going to
18 weigh in on it a little bit. But, I did want to offer
19 something that rather than making the decision on
20 whether to have a subcommittee meeting briefing and a
21 full committee, could we -- could I work with
22 Christopher Brown to maybe find the optimal solution?

23 Because two briefings take a lot of effort
24 for us, to be honest with you. Even if it's things
25 that it's administrative, and it's technical and

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1 inventory.

2 It's going to take a lot of burden. And
3 I think I'd rather use that time and staff if I'm
4 going to effectively work through is what we need to
5 complete it in the working group.

6 So we might offer a product like a one-
7 pager, or something, a small white paper on what the
8 working group is doing and stuff. And then have a
9 pre-committee.

10 But I would rather work that through
11 Christopher Brown, if that's okay with you?

12 CHAIR BALLINGER: Okay. You can go --

13 MR. IYENGAR: Rob is going to say
14 something. Go ahead Rob.

15 MR. TREGONING: Yeah. Rob Tregoning,
16 Office of Research. You know, I wouldn't be so
17 presumptuous to try to guide you much in terms of a
18 valuable letter.

19 But I would say in this environment, you
20 know, resources are tight. And we need justification
21 to do many things.

22 And even a letter that says, you know,
23 it's -- we think it's useful and valuable to update
24 the Reg Guide. And we recognize that there are still
25 questions that need to be answered in terms of

1 implications.

2 But believe -- we believe the technology
3 could be updated and should be updated. And we
4 believe the staff is in the right -- heading in the
5 right direction to address the issues that need to be
6 addressed from an implication standpoint.

7 Such a letter would be very valuable. And
8 I would not undersell the importance of such a letter
9 that would come from this august body.

10 MEMBER RICCARDELLA: I agree, if we could
11 do it in say September. But I think to do something
12 like that in November, it becomes moot.

13 You know, it -- hopefully the working
14 group --

15 MR. TREGONING: We won't -- we won't have
16 a draft Reg Guide on the street by November. So, I
17 wouldn't --

18 MEMBER RICCARDELLA: I understand. But
19 your working group.

20 MR. TREGONING: It would not be moot.

21 MEMBER RICCARDELLA: But the work group
22 will have some, presumably made some significant
23 progress by then.

24 MEMBER MARCH-LEUBA: Yeah. But if we're
25 talking a five-year time constant, two months don't

1 make much.

2 MEMBER RICCARDELLA: All right. If you
3 want us to write a letter based on what we know today
4 in November, I mean, we can do that.

5 MR. TREGONING: Yeah. Well, I think what
6 Raj is saying, is we want you to write a letter in
7 November based on the knowledge that you have in
8 November.

9 And we're going to figure out -- we're
10 going to get you as much information that we can by
11 November.

12 MEMBER RICCARDELLA: And I can support
13 that.

14 MR. TREGONING: But just recognize that
15 it's still a work in progress.

16 MEMBER RICCARDELLA: Yes.

17 MR. TREGONING: And we won't have -- all
18 the recommendations and all the implications may not
19 be fully understood by November.

20 But we'll certainly be further along then
21 we are today.

22 CHAIR BALLINGER: But Raj's proposal, or
23 suggestion of a written document, as opposed to two
24 meetings, --

25 MEMBER RICCARDELLA: A white paper.

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1 CHAIR BALLINGER: A white paper kind of
2 thing that summarizes something we can put on the
3 record for a letter related to the working group and
4 things like that, is a path forward.

5 MR. TREGONING: Sure. Sure.

6 CHAIR BALLINGER: Then you'd have to get
7 it to us and all the time --

8 MR. TREGONING: Yep.

9 CHAIR BALLINGER: Schedules and all that
10 stuff.

11 MR. TREGONING: We'd have to meet your
12 normal schedule then.

13 MEMBER RICCARDELLA: And then your
14 November presentation to the full committee could
15 summarize what you do -- you know, a much briefer
16 summary of what you did today. Plus, what's in that
17 white paper.

18 MR. TREGONING: Correct.

19 MEMBER RICCARDELLA: That would be good.

20 MEMBER REMPE: I need a break with that.

21 CHAIR BALLINGER: Yeah. I'm -- I'm -- are
22 we at a convenient point where? So Dave, do you have
23 anything to add before we take a break?

24 MEMBER PETTI: Take a break.

25 (Laughter)

1 MEMBER REMPE: Good comment.

2 CHAIR BALLINGER: Good comment. Okay.

3 Let's recess until 3:15. Then we're going to hear
4 from EPRI, I think.

5 (Whereupon, the above-entitled matter went
6 off the record at 2:57 p.m. and resumed at 3:14 p.m.)

7 CHAIR BALLINGER: Okay, we're back in
8 session. You're not supposed to smile. Okay. So,
9 Tim, you're the -- you've got to turn on the
10 microphone or get closer to it or something.

11 MR. HARDIN: Good afternoon, everyone.
12 I'm Tim Hardin from EPRI. I work in the Materials
13 Reliability Program on reactor pressure vessel
14 integrity, and I'm joined, kindly, by my colleague,
15 Nathan Palm, who is the program manager for the BWR
16 Vessel Internals Program.

17 So we've been invited to speak to you
18 today about our assessment of the NRC TLR on the
19 adequacy of Reg. I-199, Rev. 2. That line of my
20 talk basically follows the table of contents from the
21 TLR, and then I'll end with our comments on the TLR's
22 comments and recommendations.

23 Raj asked us to come and address you
24 today. The staff that had reviewed the TLR all have
25 experience in evaluating the effects of neutron

1 embrittlement; performing evaluations, PT curves, PTS
2 evaluations, reactor materials surveillance, capsule
3 evaluations, and upper-shelf energy evaluations.

4 I want to stress that this presentation
5 offers the professional opinion of the EPRI staff. It
6 is not a representation, should not be taken as a
7 representation, of an industry position from the U.S.
8 utilities. We simply did not have time to poll them
9 and get a consensus input from them.

10 So first, talking about the shift train
11 curve; I think we understand what the residuals are,
12 the residuals being the predicted minus the measured
13 values. The information in the TLR is largely
14 consistent with evaluations that we at EPRI and MRP
15 have performed to support our industry programs to try
16 to increase the amount of high-fluence data that can
17 support future development of train correlations that
18 would be applicable to operation to 60 and 80 years.

19 But what I'm going to do is briefly go
20 through those programs that we've been engaged in just
21 so you understand the context, and then I'll present
22 some of the analyses that will be useful for comparing
23 to what Dan presented earlier.

24 So we have had a concern that we don't
25 have sufficient high fluence data to inform an

1 embrittlement train curve that would be applicable to
2 these higher fluences. Just anecdotally, I've had
3 some utility executives call and ask essentially, Can
4 my reactor operate to X years; 60 years, 80 years?

5 And I try to politely say, Well, please
6 tell me what the embrittlement train correlation is
7 that we have to use at that time in order to be able
8 to answer that question. So the embrittlement train
9 correlation is very important to the commercial
10 operation of the plant, as was pointed out earlier.

11 So we developed two programs to increase
12 the amount of high fluence surveillance information:
13 that was a coordinated reactor vessel surveillance
14 program that's detailed in MRP-326, and the PWR
15 supplemental surveillance program. Both of these
16 programs have been previously briefed to the NRC
17 staff, and they are very familiar with them.

18 In the coordinated program, we just took
19 a look at the plants and their existing capsule
20 withdrawal schedules, and we identified some that
21 could significantly increase the fluence if we just
22 deferred withdrawal for 10 years or so, while still
23 maintaining compliance with ASTM E-185-82 and Appendix
24 H.

25 We implemented that program, but after

1 implementation there were still some gaps, and that's
2 why we developed the PSSP. Here, we've built two
3 supplemental capsules. We selected about 27 materials
4 to populate those capsules; those are previously
5 irradiated surveillance materials that we have
6 reconstituted into new charpy V-notch specimens. We
7 loaded them into these two capsules. We are
8 irradiating them for 10 additional years to add about
9 three times 10 to the 19th neutrons per square
10 centimeter to the existing fluence.

11 Two utilities have graciously volunteered
12 to be hosts for those capsules. The first capsule was
13 installed in Farley 1 in 2016, and the second was
14 installed last year at Shearon Harris, and they'll be
15 withdrawn in the 2027-2028 --

16 MEMBER RICCARDELLA: So you take a
17 previously broken charpy specimen and weld some -- I'm
18 having trouble making out this photograph.

19 MR. HARDIN: Yes. So we take the -- we
20 start at the top with the broken charpy specimens --

21 MEMBER MARCH-LEUBA: You need to talk into
22 the microphone and use the mouse.

23 MR. HARDIN: All right. So you start with
24 the broken charpy specimen, and those were stored at
25 Westinghouse. We obtained permission to retrieve

1 those. You machine it and shave off the broken ends,
2 and you have a specimen insert that you then weld to
3 end tabs onto the insert, machine it, and you generate
4 a new charpy V-notch specimen, which you can then load
5 into capsule and re-irradiate to add even more fluence
6 to the existing fluence.

7 MEMBER REMPE: So while we've interrupted
8 you, is the program totally funded by industry, or is
9 this part of the LWRS program, where you're
10 collaborating with DOE? How does this program --

11 MR. HARDIN: This is totally funded by the
12 Materials Reliability Program.

13 MEMBER REMPE: Okay, good. Thanks.

14 MR. HARDIN: The PWR Owners Group did
15 kindly provide some financial help to the post plants
16 to offset the costs, to defray the costs, of inserting
17 the capsules, but the fabrication of the capsules was
18 entirely an MRP project.

19 MEMBER REMPE: And you're going to keep
20 funding the examination of those specimens solely with
21 the industry-available funding? You're not depending
22 on LWRS, is what I'm asking then.

23 MR. HARDIN: That's correct.

24 MEMBER REMPE: Okay, thank you.

25 MR. HARDIN: We would be open to receiving

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1 funding --

2 (Laughter.)

3 MEMBER REMPE: I heard that because the
4 SLR was underway that some of that funding would be
5 decreasing; that's why I was wondering. Thanks.

6 MR. HARDIN: Yes, we're not counting on
7 that yet.

8 So this is a busy chart that shows the
9 future availability of high fluence surveillance data
10 relative to RPV material predicted fluence and time.
11 So on the Y axis we have the fluence, and then in the
12 years 2020, 2030, 2040, et cetera.

13 So the dark greenish data are the fluence
14 data; the surveillance data that we currently have.
15 The blueish squares are the 40-year RPV fluences
16 projected.

17 MEMBER RICCARDELLA: The open blue square?

18 MR. HARDIN: The open blue, yes.

19 MEMBER RICCARDELLA: Okay.

20 MR. HARDIN: The open purple diamonds are
21 the projected 60-year fluences for the RPV, and the
22 open red triangles are the projected 80-year fluences
23 for the RPVs.

24 The dark, filled-in blue diamonds around
25 here are the fluences of the capsules that are to be

1 withdrawn from now until 2030.

2 MEMBER MARCH-LEUBA: So somewhere around
3 this year or next year, we're going to get a large
4 number, half a dozen, between five and 10 --

5 MR. HARDIN: Yes.

6 CHAIR BALLINGER: So that data is the
7 Shearon Harris and Farley?

8 MR. HARDIN: No, no. These are the
9 regular capsules, Appendix H capsules, in many
10 different plants, operating plants. The PSSP capsules
11 from Shearon Harris and Farley are the green --

12 CHAIR BALLINGER: That's what I thought.

13 MR. HARDIN: Yes, the green triangles.

14 MEMBER RICCARDELLA: And those way up at
15 the top?

16 MR. HARDIN: Yes.

17 MEMBER RICCARDELLA: So those two ones way
18 at the top?

19 MR. HARDIN: Yes.

20 CHAIR BALLINGER: Well, plus all of the
21 green triangles, right?

22 MR. HARDIN: Yes, correct.

23 MEMBER RICCARDELLA: Your eyes are better
24 than mine. I only see those two.

25 MR. HARDIN: Okay. All right. So that

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1 gives a perspective that we're going to be able to
2 obtain bounding fluences well before the RPVs actually
3 reach the peak fluences.

4 CHAIR BALLINGER: Are these typical copper
5 and nickel plants?

6 MR. HARDIN: What, the PSSP?

7 CHAIR BALLINGER: Yes.

8 MR. HARDIN: Well actually, those were
9 carefully selected, and I'm going to discuss that a
10 little bit in subsequent slides.

11 But we looked at the regular capsules, the
12 Appendix H capsules that were going to be available,
13 and then we looked at gaps in terms of product forms
14 and chemistries that were not well-represented, and we
15 chose materials to fill those gaps. That's the
16 materials we put on the PSSP so that those materials
17 would more fully inform embrittlement train
18 correlation.

19 So as I said, we looked at all the RPV
20 surveillance materials in the U.S. We divided them
21 according to product form and chemistries, and then we
22 evaluated how well the existing embrittlement train
23 correlations predicted that group.

24 And if we had a poorly-predicted group, we
25 targeted that for inclusion in the PSSP in order to

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1 get some data down the road that more robustly will
2 describe that. And that is published in MRP-364,
3 which is not yet publicly available, but also this PVP
4 paper, which is publicly available.

5 So we looked at Reg. I-199, Rev. 2,
6 EONY, the Eason Odette Nanstad and Yamamoto
7 correlation that is used in the alternate PTS rule, 61
8 alpha. At WRC 5, Rev. 1, which was a correlation
9 developed by Mark Kirk, and I think it's fair to say
10 that that was the forerunner to become ASTM E 900-15.
11 And then more recently we've gone back, and in a few
12 of the slides that I'll show, we actually indicated
13 the results using the ASTM E 900-15, because it is
14 most recent and accurate correlation.

15 So the slides only include U.S. PWR
16 radiations, and only the 41 joule index temperature
17 shift measures are shown.

18 So here we have an example for low copper
19 but nickel-added, higher nickel plates. The red
20 squares, solid, are the reg guide. The green circles
21 are EONY, alternate PTS rule. And then the yellow
22 triangles are E 900-15.

23 And for this particular product form and
24 chemistry, all three, the mean of the correlations is
25 pretty flat and around zero axis. However, one train

1 that you can take away here is that scatter is
2 increasing significantly as the fluence increases.
3 That gets back to the points that Dan made earlier.
4 Sir?

5 MEMBER MARCH-LEUBA: Do you have any gut
6 feeling for what the safety significance of 40 degree
7 Fahrenheit inaccuracy in your prediction? So I'm
8 drawing the 2-sigma plus minus 40. Is that as
9 significant safety impact on a plant or operational
10 significance for a plant? Or you say, Oh, never mind?
11 I have no idea.

12 MR. HARDIN: First, let me preface it. We
13 have done a deliberate study of that, but I would tend
14 not to think it is, for the reason that, even in cases
15 where you have a significant underprediction, then you
16 have -- we'll talk about the Whitman slides -- you
17 have a provision where the higher chemistry factor
18 that is determined by the surveillance data is
19 required to be used for evaluational vessel material.

20 MEMBER MARCH-LEUBA: No. The question I'm
21 asking is, say that you have older chemistry; you have
22 older input parameters. Now, I'm also operating here,
23 and now my number suddenly changes to minus 40 degrees
24 Fahrenheit.

25 Does that take 10 years off the life of my

1 plant, or does it require me to operate in a different
2 domain? Or is 40 degrees, no, never mind; unless you
3 get to 500 degrees, it's not an issue?

4 MR. HARDIN: Right.

5 MEMBER MARCH-LEUBA: It's not significant.

6 MR. HARDIN: Yes, I agree; it depends. It
7 may affect the period of time for which the PT limit
8 curves are --

9 MEMBER MARCH-LEUBA: -- useful. So it
10 can't cut the life of the plant? Forty degrees can't
11 --

12 MR. HARDIN: I wouldn't say life of the
13 plant, but it might -- because typically plant doesn't
14 do PT curves out to the end of its license. It does
15 maybe 10 years in advance until it knows it has to
16 redo another set of PT curves.

17 So if you have a significant non-
18 conservatism like this, it might make the period of
19 applicability for those PT curves shorter.

20 MEMBER MARCH-LEUBA: And then when you re-
21 evaluated, you -- you're still in compliance?

22 MR. HARDIN: Well --

23 MEMBER MARCH-LEUBA: I have no idea.

24 CHAIR BALLINGER: Change the operation.

25 (Simultaneous speaking.)

1 MEMBER RICCARDELLA: You change the
2 operation. The peak curve means what the maximum
3 pressure you can go to at any given temperature, so
4 you'd have to heat up --

5 MEMBER MARCH-LEUBA: So how close do we
6 operate from limits? I mean, is 40 degrees
7 significant? Does it eat into my limits?

8 CHAIR BALLINGER: It depends on where your
9 starting point is, don't you think?

10 MR. HARDIN: Right. I mean, first off, it
11 would have to be the controlling material on which
12 your limits are based. So if it's a material that
13 isn't controlling, then the question is, is the
14 limiting material less than 40 degrees from that
15 material?

16 And then even after that, okay, is it a
17 plate, or is it an axial weld, or is it a
18 circumferential weld? Because if it's a
19 circumferential weld, it may not have as large an
20 impact. And then at that point you would evaluate
21 whether it would change the applicability.

22 And I guess, even if it's a fairly -- if
23 it's a plant that does have high ART values, then the
24 limits could be more restrictive, and you may be
25 closer to operation. But if you're talking about a

1 boiling model, well, this is PWR data; I don't know.

2 But if you were talking about a lesser
3 irradiated PWR or a BWR, chances are you're going to
4 be operating pretty far from the PT limits curve to
5 begin with.

6 MEMBER MARCH-LEUBA: So it's applied to a
7 specific number.

8 MR. HARDIN: Yes. And I think that's
9 where the staff, when they had some of those
10 questions, I think that was some of the difficulty
11 they were having giving you a precise answer, because
12 it really depends on so many various factors.

13 MEMBER MARCH-LEUBA: Just -- I'm not
14 complaining, I'm asking you to educate me, okay?
15 Because I don't know anything about it.

16 CHAIR BALLINGER: Remember that they are
17 dealing in Fahrenheit; the staff is dealing in
18 centigrade.

19 MR. HALL: I'm Brian Hall with
20 Westinghouse. I might be able to help a little bit.

21 So the margin term in the reg guide is
22 designed to deal with that uncertainty. And as the
23 staff pointed out, the data shows that the standard
24 deviation is probably a little bit higher than what is
25 in the reg guide with the additional data, and that's

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1 what this is showing too, consistent with that.

2 So to answer your question, the
3 uncertainty might be a little bit larger than what the
4 reg guide says, but I wouldn't say it's a safety
5 significance, at least not in the next decade or two.

6 MEMBER RICCARDELLA: So do I read this,
7 that those yellow triangles are higher than -- I mean,
8 it's showing improvements as you go from Reg. I-199
9 to the ASTE 900 one, I guess. Is that right?

10 MR. PALM: Yes, sir.

11 MR. HARDIN: And I think what Nathan
12 pointed out earlier, the significance of it really
13 does depend on if the specific material is your
14 limiting material or not. In the vessel, you have
15 welds; you have plates. And this is for a plate.

16 Well, if you have a significant non-
17 conservatism in the plate, that plate's adjusted
18 reference temperature may be 60 degrees below the
19 limiting weld, and the plant already operates to that
20 limiting weld. So this would have no impact at all on
21 the plant operating limits.

22 Another example, low copper, low nickel
23 welds. As we saw from Dan's presentation, welds are
24 fairly well represented by the reg guide, as well as
25 the other train correlations.

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1 That is not the case for all product
2 forms, however. We have an example here of medium
3 copper forgings, where there seems to be a distinctly
4 negative trend for the reg guide in the non-
5 conservative direction.

6 The prediction of embrittlement by the reg
7 guide; a little bit of a negative trend by EONY
8 correlation. E 900-15 does a pretty good job all the
9 way up until one times 10 to the 20.

10 But, again, it's a very complex situation.
11 Here's also forgings, same as the previous slide, but
12 now it's high copper. The reg guide fairly
13 consistently overpredicts embrittlement, so it's going
14 to be a very complex situation to figure out.

15 Here's a table that summarizes all the
16 various groups, and this describes how we broke them
17 up into 302B modified and 533 B1 plates, 302B plates,
18 forgings, and then welds, high nickel and low nickel.

19 We've characterized it as using three
20 symbols: an O for overpredicts, a U for
21 underpredicts, and then in some cases we found that
22 there was a distinct change in the capability of the
23 reg guide to characterize the shift at about three
24 times 10 to the 19th.

25 Once it got -- you know, sometimes it was

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1 overpredicting below three times 10 to the 19th, but
2 underpredicting above three times 10 to the 19th. So
3 in those cases where you see a slash mark, that's what
4 that is indicating.

5 You can see the EONY fit is better than
6 the reg guide in most of these instances. We did not
7 have a full set of E 900 data, so that was not
8 included on this chart.

9 But the main takeaway, I think, from these
10 slides that I've shown is that the mean trends very
11 significantly as a function of product forming
12 chemistry, and overall, the scatter and the residuals
13 for Reg Guide 199, Rev. 2 increase significantly with
14 increasing fluence.

15 Some other comments on the TLR; Section 2
16 states that not all plants use the reg guide shift
17 train curve directly as many supplement it with
18 surveillance data or other adjustments such as the
19 degree per degree.

20 We thought that this statement understates
21 the use of the reg guide in the fleet. All plants use
22 Reg Guide 199 directly for any materials where there
23 is not surveillance data. And for most RPVs that's
24 most of the RPV materials, because in RPV you can have
25 six, eight plates and several welds.

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1 In your surveillance program you typically
2 have one plate, one weld, one HAZ. So you can use the
3 surveillance data from the capsules for those matching
4 materials in the vessel. But for all the other plates
5 and all the other weld numbers, you have to use Reg.
6 I 199, Rev. 2.

7 MEMBER MARCH-LEUBA: But is that because
8 it has a different fluence, or because it has --
9 because it should be the same chemistry.

10 MEMBER RICCARDELLA: No.

11 MR. HARDIN: No, they're significantly
12 different.

13 MEMBER MARCH-LEUBA: Okay. I don't
14 understand how --

15 MEMBER RICCARDELLA: But in general,
16 aren't the surveillance specimens intended to be the
17 limiting materials, or no?

18 MR. HARDIN: When they are --

19 MEMBER RICCARDELLA: Intended; I used the
20 word intended.

21 MR. HARDIN: They were intended to --

22 MEMBER RICCARDELLA: But they're not
23 always?

24 MR. HARDIN: That's correct, because you
25 have -- the surveillance program was established when

1 the vessel is built, so a lot of these materials were
2 established in the '60s and '70s under the original
3 reg guide, and the guidance for prediction of
4 embrittlement has undergone several changes.

5 MEMBER RICCARDELLA: We didn't know about
6 copper back then.

7 MR. HARDIN: Yes, exactly. So now we know
8 that other materials can be a limiting material.

9 Other comments, and these are really just
10 observations. To currently apply a weld surveillance
11 data to evaluate if that's a weld with the same heat
12 number, if there is a significant difference in
13 chemistry between the surveillance weld and the vessel
14 weld of the same heat number, then we use the
15 chemistry factors from Reg. Guide 199, Rev. 2, Table
16 1 in a ratio procedure to adjust the surveillance
17 shift to what would be applicable to the vessel weld.

18 If a new reg guide is adopted that does
19 away with chemistry factors, then it would be
20 necessary to develop alternate guidance for how to
21 make that adjustment to apply surveillance weld shifts
22 to vessel welds.

23 The TLR references the Wickman-Hiser-
24 Mitchell slides. Those were the three co-authors on
25 those 1988 slides, but does not mention the same

1 guidances available in summary form in NUREG 15-11,
2 Supplement 2.

3 Charpy upper shelf energy train curve;
4 EPRI has also done some work in this area. We saw the
5 presentation many years ago by Mark Kirk; the slide
6 that there was the Reg. Guide 199, Rev. 2, Upper
7 Shelf Energy Decrease Prediction may be non-
8 conservative.

9 We know that Dr. Kirk generated the UNM
10 6 correlation to achieve a 2-sigma pound, and we
11 reviewed that. We're concerned with that correlation,
12 that it might unfairly penalize non Linde 80 welds and
13 cause significantly more materials to fall below 50-
14 foot pounds than is really necessary.

15 So we started in a research project;
16 Westinghouse was our vender on this work. Brian Hall
17 in the audience was one of the authors. We published
18 MRP-414 in 2017; that's not yet available, but we also
19 published a PVP paper, which is publicly available and
20 provides the upper-shelf energy prediction curve that
21 we developed from this work.

22 We had over 1,500 upper-shelf energy
23 change measurements in this database, only from LWRs
24 from U.S., Korea, Germany, Brazil, Spain, Mexico,
25 Sweden, and France. We screened that material or

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1 those data, and after screening had about 1,177 that
2 was used for modeling.

3 We investigated two types of models: one
4 that used ASTM E 900-15 as the primary input
5 parameter, and one that did not. In the end, just to
6 reduce complexity, we decided to go with the one that
7 did not use the E 900-15 transition temperature shift
8 correlation.

9 We evaluated the effect on the fleet and
10 found that basically we were able, with this
11 correlation, to attain a 2-sigma bound on the upper-
12 shelf energy decrease data but have negligible
13 increase in the number of PWRs that would be predicted
14 to fall below 50-foot pounds.

15 In our correlation there were 30 PWRs in
16 92 materials that were predicted to fall below 50-foot
17 pounds. The reg guide would be 30 PWRs and 82
18 materials.

19 So we do -- in our correlation in order to
20 give that 2-sigma bound. We do have more materials,
21 but the same number of overall PWRs. So our comment
22 here would be if NRC desires to pursue a revision of
23 the reg guide upper-shelf energy decreased prediction
24 model, we would suggest consideration of the model
25 that is in MRP 414. Yes, sir?

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1 MEMBER MARCH-LEUBA: What's an EMA?

2 MR. HARDIN: An EMA -- sorry if I did not
3 -- I thought --

4 MEMBER MARCH-LEUBA: No, I simply don't
5 know these --

6 MR. HARDIN: Equivalent Margins Analysis.

7 MEMBER MARCH-LEUBA: And you do that once
8 every 10 years?

9 MR. HARDIN: No. That is Appendix G, 10
10 CFR 50, Appendix G. It requires that all reactors
11 vessel outline materials maintain at least 50-foot
12 pounds upper-shelf energy through the end of license.
13 And if you're ever predicted to fall below 50-foot
14 pounds, then you have to do an analysis that shows
15 that an equivalent safety margin exists, and that's
16 what an equivalent margins analysis is.

17 MEMBER MARCH-LEUBA: Oh, so that MRP 414
18 is a correlation?

19 MR. HARDIN: It's a correlation.

20 MEMBER MARCH-LEUBA: That is not a real
21 value; it is a screening criteria.

22 MR. HARDIN: Correct.

23 MEMBER MARCH-LEUBA: If you pass it, you
24 don't have to do anything else. You fail it, you have
25 to do more details.

1 MR. HARDIN: If you use it and it falls
2 below 50-foot pounds -- if that were being used as a
3 regulatory benchmark -- then just like with the reg
4 guide, if you use a reg guide, fall below 50-foot
5 pounds, then you would need to do an equivalent
6 margins analysis.

7 MEMBER MARCH-LEUBA: I didn't realize
8 that. So it is a screening criteria; it doesn't need
9 to be active.

10 MR. PALM: Is that an EPFM electric
11 plastic? The margins analysis, is that a --

12 MR. HARDIN: EMA is an elastic plastic
13 fracture mechanics analysis that's governed by
14 Appendix Echo and K and Reg. Guide 1.164.

15 MR. PALM: Yes. To clarify, MPR 414 does
16 not include an equivalent margins analysis. It is
17 just providing an alternate upper-shelf energy
18 decrease prediction model.

19 MR. HARDIN: And the embrittlement train
20 correlation for upper-shelf energy, basically.

21 MR. PALM: Yes.

22 MR. HARDIN: Then there's another section
23 in Section 3 of the TLR. It states that the reg guide
24 predictions for the shift in upper-shelf energy
25 contain a conservative bias. Attention is called to

1 the last sentence: Further work is needed to evaluate
2 the regulatory significance of the current 68-joule
3 criteria and to determine if it should be retained,
4 modified, or eliminated.

5 Generally we agree with this overall
6 paragraph in the TLR, but we do observe that the
7 requirement for 68 joules or 50-foot pounds is
8 established in 10 CFR 50, Appendix G, not the reg
9 guide. So if you're going to talk about modifying or
10 eliminating it, that suggests rulemaking to change
11 Appendix G.

12 MEMBER RICCARDELLA: As I recall from a
13 long time ago, RTndt was based on drop-weight ndt, and
14 then a certain number of degrees above that you have
15 to have 50-foot pounds, six degrees above that. And
16 that's RTndt. Is this 30-foot pound number kind of
17 used as a surrogate for that as the actual RTndt?

18 MR. HARDIN: I'm sorry, I'm not getting
19 where you get 30-foot pounds.

20 MEMBER RICCARDELLA: No. We're using this
21 charpy CVN of 30-foot pounds as basically a shift in
22 RTndt. But that's a surrogate for the real RTndt,
23 right, more or less?

24 MR. HARDIN: That's the transition
25 temperature, index temperature on the charpy curve.

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1 MEMBER RICCARDELLA: Yes.

2 MR. HARDIN: And that is used as a -- the
3 difference between the T 41 joule or T 30-foot pound
4 temperature for the unirradiated material and the
5 irradiated material; that shift is assumed to be the
6 shift in Rtndt.

7 CHAIR BALLINGER: Are you referring to the
8 Polini -- the original Polini drop-weight test, where
9 this was all derived from.

10 MR. HARDIN: Yes. The original --

11 CHAIR BALLINGER: They took a weld, put it
12 in a plate, dropped something on the thing --

13 MEMBER RICCARDELLA: But you can't do a
14 balance drop-weight test, so you use the 30-foot pound
15 as a surrogate.

16 MR. HARDIN: But all that testing was the
17 beginning of lack to establish the original values,
18 the drop weight and the charpy.

19 Now, in continued testing that goes on is
20 the charpy testing from the surveillance capsules.

21 On fleet impact in Section 3 of the upper-
22 shelf energy train curve evaluation states that for
23 this assessment, preliminary estimate of the number of
24 reactors may fall below 68 joules, criterion of
25 measure, but are not predicted to do so, was

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1 conducted.

2 So it goes on, and I think we discussed
3 this a little bit earlier. That chart got a lot of
4 discussion that Dan showed, that there were some
5 plants that might be predicted to fall below 50-foot
6 pounds, but are not predicted by the reg guide to fall
7 below 50-foot pounds. In their statement, these
8 plants warrant further review.

9 But we felt that that statement should be
10 clarified or revised because it implies an inadequacy
11 in the existing upper-shelf energy calculations for
12 some four plants and could be interpreted as a
13 regulatory challenge, questioning the plant license
14 basis.

15 Those upper-shelf energy calculations
16 are performed by the current NRC guidance; the current
17 guidance is Reg. Guide 199, Rev. 2, so the post
18 plants are fully in compliance, and those calculations
19 have been reviewed by the NRC. So we felt it would be
20 inappropriate to imply that there is some sort of
21 regulatory action required for those plants.

22 MEMBER RICCARDELLA: Were these comments
23 addressed? You're making all these various --

24 MR. HARDIN: No. I believe this is the
25 first time the staff has seen this.

1 MEMBER RICCARDELLA: Okay, okay. So we
2 reach out for comment? The status is, this is still
3 out for public comment?

4 MR. IYENGAR: So this TLR was not for
5 release for public comment; it was just released for
6 us.

7 CHAIR BALLINGER: Yes, this is just for
8 us.

9 MEMBER RICCARDELLA: Okay.

10 MR. IYENGAR: Normally it's not a process
11 that we release every TLR for public comment,
12 especially --

13 MEMBER RICCARDELLA: But you sent a copy
14 to EPRI?

15 MR. IYENGAR: Right. And we would
16 consider whatever comments we get from EPRI, as well
17 as other stakeholders.

18 MEMBER RICCARDELLA: Okay. Thank you.

19 MR. HARDIN: Credibility criteria and use
20 of surveillance data; the TLR states in Section 4.1
21 that should the data be deemed non-credible, the user
22 is directed to discard the chemistry factor refit,
23 losing what may be a superior data fit, Reg. Guide
24 199, trim curve.

25 Our comment here is that while this may be

1 consistent with the reg guide as written, it is not
2 consistent with how the NRC has implemented the
3 guidance in the Wickman slides from 1998.

4 That is, if a fitted chemistry factor --
5 that is, the chemistry factor you calculate for
6 surveillance data -- and it's non-credible, it is
7 higher than the table base, the reg guide table base
8 chemistry factor, then the NRC has required the use of
9 the higher non-credible surveillance chemistry factor
10 to be used in calculation of the adjusted reference
11 temperature.

12 MEMBER MARCH-LEUBA: Higher meaning
13 conservative or non-conservative?

14 MR. HARDIN: Conservative.

15 MEMBER MARCH-LEUBA: Conservative.
16 Negative is bad, but --

17 MR. HARDIN: Right. So you take the --
18 even if it's non-credible surveillance data, if it's
19 a higher chemistry factor, you're required to use it.

20 MEMBER RICCARDELLA: Okay. So it can hurt
21 you, but it can't help you. Is that what you're
22 saying?

23 MEMBER MARCH-LEUBA: So why do you put
24 your samples in there?

25 MR. PALM: Because you're required. If

1 the data is credible and it's lower, you can use it.
2 But if it's higher and it's credible or non-credible,
3 you use it. The caveat is, if it's credible, you can
4 use a reduced margin term, and if it's non-credible,
5 you use the full margin term.

6 MR. HARDIN: So often surveillance data is
7 very helpful to plants because it's often credible,
8 and they can cut the sigma-delta by half and reduce
9 the calculated adjusted reference temperature for that
10 material.

11 MEMBER MARCH-LEUBA: But do you agree with
12 the process of determining whether it is credible or
13 non-credible? Because I thought that the sample they
14 showed us an hour ago, they run a perfectly clearly --
15 statistical test, and it failed the reg guide.

16 They did a beautiful mathematically
17 correct data, and the reg guide said it wasn't
18 credible. So I think that's what they have, right?

19 So, I mean certainly in the -- your
20 comment but it appears that the process specified in
21 the reg guide to determine credibility of data has a
22 hole in it. It projects more good than it should.

23 MR. HARDIN: I would not disagree with
24 that. I do want to point out that in a later slide,
25 credible surveillance data has been very helpful to

1 the plants to resolve issues.

2 MEMBER MARCH-LEUBA: In my opinion, you
3 should always believe an experiment over anything else
4 unless you really, really have a reason to doubt it.

5 MR. HARDIN: So the credibility criteria
6 is difficult, but it still has been very helpful.

7 Neutron embrittlement, neutron
8 attenuation; EPRI has sponsored some testing
9 activities on this, starting back more than 10 years
10 ago, I think. There was an IAEA research program that
11 was designed and run by Nuclear Research Institute,
12 Czech Republic. NRI was in Czech Republic, and as a
13 matter of fact, I think NRC was involved in some way,
14 in that I think some materials were contributed by NRC
15 for that experiment.

16 EPRI contributed a Linde 80 weld and a
17 high-copper SA58 533B plate. Then after that
18 experiment was conducted -- this was at a Russian
19 reactor, but the Czech Research Organization performed
20 the testing, and EPRI paid for various parts of that
21 testing; hardness testing, master curve TZ0 testing,
22 tensile testing, charpy testing.

23 And so there are a series of reports that
24 I've listed here on the slide. The PLR references a
25 server 210, which is a summary paper that was based on

1 all those various MRP reports.

2 Anyway, this research basically supports
3 the TLR regarding issued of attenuation. We've also
4 conducted analyses of neutron attenuation in PBR
5 nozzles. In 2012 we released MRP 345, and this is a
6 publicly available report.

7 And this research also supports the
8 conclusions of the TLR that the reg guide attenuation
9 formula is not applicable in the extended belt line
10 and nozzle region, because the peak DPA rate occurs on
11 the outside surface of the nozzle, forging the bottom
12 of the nozzle in the cavity regions.

13 So this plot here is a DPA rate versus
14 fraction of distance through the nozzle, where the
15 zero starts at the corner of the nozzle at this red
16 line, and then continues at a 45-degree angle. So
17 that's where this DPA rate is measured from, plotted
18 from.

19 So you can see that actually the DPA rate
20 increase through the thickness of the nozzle; does not
21 attenuate as the reg guide would predict.

22 MEMBER RICCARDELLA: What's the difference
23 between the blue and the red curve?

24 MR. HARDIN: Inlet nozzle, outlet nozzle.
25 One curve, the red curve, is for the outlet nozzle;

1 the blue curve is for the inlet nozzle.

2 MEMBER RICCARDELLA: But it doesn't
3 attenuate? It increased?

4 MR. HARDIN: Right. Because you have an
5 albedo effect of neutrons leaking out the cavity and
6 impacting the exit to reactor vessel laterally, maybe
7 interact with a biological shield bounced up in the
8 cavity and --

9 MEMBER RICCARDELLA: That's what is
10 referred to as streaming?

11 MR. HARDIN: Yes. Now, of course it's
12 plant-specific. You would not have this configuration
13 or this concern if the vessel was supported by a
14 shield tank, for example.

15 MEMBER RICCARDELLA: Okay.

16 MR. HARDIN: This is more applicable to
17 something on support beams.

18 I will note that there is ongoing research
19 that may impact the evaluation of neutron attenuation
20 in vessels. There are experiments being supported by
21 DOE: light water reactor sustainability program on
22 the decommissioned Zion 1 RPV beltline. Material was
23 removed from the beltline, shipped to Oak Ridge, and
24 Oak Ridge has cut samples through thickness, measured
25 through thickness properties, through thickness,

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1 charpy impact and chemistries --

2 MEMBER RICCARDELLA: Chemical harvesting?

3 MR. HARDIN: Yes. And so to my knowledge,
4 this is the first time we've done something like this:
5 taken actual RPV wall that has been in service and
6 then doing -- testing. So it should inform future
7 guidance on the effects of attenuation.

8 MEMBER MARCH-LEUBA: You need to, for
9 neutron attenuation, you really don't need to run an
10 experiment. You just take MCMP; wait sufficient --
11 enough samples. It might take you several weeks on a
12 supercomputer, but you will get a neutron flux, and
13 you know the standard deviation of the neutron flux.

14 MEMBER RICCARDELLA: What's MCMP?

15 MEMBER MARCH-LEUBA: It's the Monte Carlo
16 Code.

17 MEMBER RICCARDELLA: A computer program.

18 MEMBER MARCH-LEUBA: Well, talk to the
19 expert.

20 CHAIR BALLINGER: Transport.

21 MEMBER MARCH-LEUBA: It tracks the path of
22 a neutron and into billions of neutrons, and you get
23 the right -- for attenuation, there is no issue. You
24 don't have to do the experiment. It can be an
25 expensive operation.

1 (Simultaneous speaking.)

2 MEMBER RICCARDELLA: It can be very useful
3 and accurate in complex geometries, and that's been
4 demonstrated in many applications.

5 MR. HARDIN: That gives you a very
6 accurate understanding of what the neutrons are doing,
7 the flux is doing. It doesn't necessarily tell you
8 what's happening to the material.

9 MEMBER MARCH-LEUBA: You need to have the
10 responsive material to the neutrons, but it has
11 nothing to do with attenuation. Attenuation, you can
12 calculate it if you're willing to wait enough time,
13 because it takes billions and billions of traces,
14 you'll get it.

15 MEMBER RICCARDELLA: Yes. You get the
16 neutrons, but then you try to correlate that with what
17 the toughness is, and you get that huge scatter.

18 MEMBER MARCH-LEUBA: Well, I assume you
19 people know what the neutron does to your material.

20 CHAIR BALLINGER: Yes, but going from
21 neutron energy to actual displacements --

22 MEMBER MARCH-LEUBA: Well, it actually
23 calculates the displacement of --

24 MEMBER RICCARDELLA: EPA?

25 MEMBER MARCH-LEUBA: -- what every

1 electron in the material ends up.

2 MEMBER RICCARDELLA: I don't care about
3 electrons.

4 (Simultaneous speaking.)

5 MEMBER MARCH-LEUBA: If you want to, you
6 can track every electron that gets displaced.

7 MEMBER REMPE: But I think what he's
8 trying to tell us is that you may be able to
9 understand what the fluence is, but you may not know
10 what the material response is for that fluence.

11 So I think if the wording were changed
12 here, that would help our colleagues here, but you are
13 doing, just to make sure I understand, material
14 property testing. You're not just doing evaluations
15 of attenuation, right?

16 MR. HARDIN: Attenuation, that is right.
17 That is what Oak Ridge is doing. That's an effort
18 entirely funded by light water reactor sustainability
19 program. EPRI is not involved.

20 MEMBER RICCARDELLA: The Zion --

21 MR. HARDIN: The Zion work, yes.

22 MEMBER REMPE: And that work is fully
23 funded, and not -- there's no concerns about future
24 efforts. It's going to be finished in 2019?

25 MR. HARDIN: It might not be fully funded

1 yet. The charpy --

2 MEMBER MARCH-LEUBA: My point is, the reg
3 guide uses a correlation for the attenuation of the
4 neutrons. If you don't like the correlation, you can
5 run MCMP and calculate the real one.

6 MR. HARDIN: The only reason I put it on
7 here is because it pertained to a topic that's in the
8 TLR. I've seen that presentation twice now, and I
9 think it has information that NRC staff should
10 consider. So I'm just trying to call it to their
11 attention.

12 MEMBER RICCARDELLA: Is it charpy -- is it
13 doing charpy tests? A Zion --

14 MR. HARDIN: It's charpy testing and
15 chemistry.

16 MEMBER RICCARDELLA: Chemistry. Okay.

17 MR. HARDIN: Actually, one of the authors
18 is here, Dr. Nanstad.

19 MEMBER MARCH-LEUBA: So for future
20 reference, speak into the microphones so it ends up on
21 the record. And your name, please?

22 MEMBER RICCARDELLA: We need to get your
23 name on the record.

24 MR. NANSTAD: So I'm Randy Nanstad, RNS
25 Consultants. I'm here representing the light water

1 reactor sustainability program at Oak Ridge.

2 So the Zion work, yes, there are charpy
3 specimens, tensile specimens, and fracture toughness
4 specimens, as well as chemical composition specimens
5 that are being tested mechanically through the
6 thickness of that eight-inch thick vessel.

7 And then there are microstructural
8 investigations, et cetera, that are being done to
9 supplement the mechanical properties.

10 MEMBER MARCH-LEUBA: So that doesn't
11 really agree with the information. Is there neutron
12 flux fluence for were characterized for the sample?

13 MR. NANSTAD: Well, what we have is the
14 information that was available from Westinghouse in
15 terms of the flux and fluence on that vessel. We have
16 not done any experiments to try and determine if the
17 plant shut down in 1995 --

18 MEMBER MARCH-LEUBA: You'll have to do
19 some calculations or believe Westinghouse. Hopefully,
20 Westinghouse has not used the incorrect attenuation
21 curve. What we've seen is that if you go off the
22 horizontal plane, the attenuation curve is not
23 correct.

24 MR. NANSTAD: I'm sure they did.

25 MR. HARDIN: Common additions to Reg. I

199; the TLR discusses the use of sister plant data. This is more of an editorial comment. We use this term repeatedly, sister plant data. To some extent, we feel it's a misnomer, and its concept not well-defined.

In practice, it's matching heat number data, because that's what you're doing. Surveillance materials with heat numbers that match vessel material heat numbers are considered when evaluating the integrity of those materials in the vessel, whether or not the data originates from a sister plant.

It could come from a supplemental surveillance capsule, for example, not necessarily a sister plant. So that was just an editorial comment.

The TLR also states that consequently, the addition of sister plant data increases the likelihood that plant-specific data would be rejected. I think we spoke to this, that there are some very high-profile instances where it has been very helpful to plants to have sister plant data and to apply sister plant data.

Comments about implementation of future revisions to Rev. Guide 199; obviously, the adoption of new guidance in predicting embrittlement will have a significant impact on all operating plants and also

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1 the international plants that use Reg. Guide 199,
2 Rev. 2. That would affect PT curves, low temperature
3 over pressure setpoints, et cetera.

4 When the last update, Rev. 2, was
5 introduced in 1988, it was introduced with somewhat
6 onerous requirements for a quick impact assessment and
7 adoption. Now, at that time, that was probably
8 justified, because there was so little surveillance
9 data available, and the train correlation of Reg.
10 Guide 199, Rev. 1 was notably non-conservative. So
11 that's understandable.

12 But we do think -- our comment is that the
13 data presented in the TLR that we discussed earlier,
14 showing that plants only start to reach levels that
15 are of serious concern in the late 2020s -- and those
16 are only the earliest plants. There are many lower-
17 fluence plants that will not reach that until much
18 later -- suggests the phased implementation of any
19 revision to Reg. Guide 199, Rev. 2.

20 And finally, our comments on the
21 conclusions and recommendations; we do find the
22 conclusions of the TLR succinct and their technical
23 biases are thoroughly documented.

24 The only exception is that statement about
25 the four plants with upper-shelf energy that need

1 further review. That may be true on a research basis,
2 but we felt it was worded sort of in a licensing
3 basis. That was our concern there.

4 The recommendations of the TLR were
5 reasonably supported by the analyses presented and
6 were generally consistent with our research. The EPRI
7 shelf energy prediction model is available for
8 consideration if NRC wants to update that model.

9 A new high-fluence dataset will become
10 available in 2028, 2030 when the PSSP capsules are
11 tested. That will provide a means for future
12 validation of the revised reg guide or to inform
13 development in the future embrittlement train
14 correlations.

15 And then finally, the data seem to support
16 a phased implementation of any revision to the reg
17 guide in order to minimize unnecessary burden on the
18 operating fleet.

19 That's all we had today. Any additional
20 questions? Sir?

21 MEMBER MARCH-LEUBA: Yes. Go back one.
22 Why in that supports a phased implementation? That
23 last comment. What in the -- you said the data
24 supports a phased implementation. I think you would
25 prefer to have a phased implementation, but what in

1 the data supports a phased implementation?

2 MR. PALM: Yes. What he's referring to is
3 the fact that we really don't see these larger
4 residuals or scatter occurring until higher fluences,
5 and there are many plants, lower fluence PWRs and most
6 of the BWR fleet, will never come anywhere near those
7 fluences.

8 If you go back to the slides that were
9 presented by Dan and look at the left-hand axis; look
10 at the data to the left of -- the scatter is still
11 within the predicted scatter. We don't see any
12 unreasonable deviations or trends in either direction.

13 So for those lower-fluence plants, there's
14 no immediate need for them to update their PT limit
15 curves. I think just as an example of what we were
16 thinking in terms of phased implementation, they could
17 update to the next reg guide revision perhaps when
18 another licensing basis need arises.

19 So perhaps when they have another
20 surveillance capsule that needs to be taken into
21 consideration, they would use the new reg guide at
22 that time.

23 MEMBER RICCARDELLA: If you've got five
24 plants that are affected and that potentially have a
25 regulatory issue, and 90 plants that -- yes, the

1 correlation's not great, but it's not a safety
2 concern, why should those 90 plants have to go back
3 and revise their PT curves? I think that's what he
4 said.

5 MEMBER MARCH-LEUBA: Okay. But I wouldn't
6 call that phased-in implementation. What I see in the
7 letter is that most of the used plants have to be
8 below five to six times 10 to the 19th. That's what
9 all the red dots in the famous -- they're all below
10 five to six.

11 But when we go above five, and certainly
12 when we went to 20, there is a real trend, most of
13 them in foreign plants, that clearly we do not predict
14 properly.

15 So the obvious solution to this on Reg.
16 Guide Rev. 2 is for plants that have a fluence of
17 less than five times 10 to the 19th, you don't have to
18 do anything.

19 MEMBER RICCARDELLA: Right.

20 MEMBER MARCH-LEUBA: Is that what you mean
21 by phased?

22 MR. PALM: You wouldn't need to do
23 anything immediately.

24 MEMBER MARCH-LEUBA: Right. So I don't
25 see tying it to a future action that the plant chooses

1 to do, versus tying it to the condition of the plant.
2 So if you are less than five times 10 to the 19th, the
3 data suggests that new correlation and old correlation
4 are going to give you the same number. You don't need
5 to do anything.

6 MEMBER RICCARDELLA: Not the same; the
7 new correlation might give you a better number.

8 MEMBER MARCH-LEUBA: It might, but if you
9 go and plug it in, 50 percent of the plants will come
10 up higher; 50 percent of the plants will come up
11 lower. So you're better off not touching it.

12 MEMBER RICCARDELLA: Well --

13 MR. PALM: I mean, maybe it doesn't
14 necessarily need to be tied to a licensing basis
15 action, but if you give them the flexibility, and they
16 come up on one of those actions, like a new
17 surveillance capsule, and they can look out in the
18 future and say, We're not at that fluence threshold at
19 this point in time, but we're not going to have
20 another licensing basis action before we reach that
21 fluence threshold, then they would be able to go ahead
22 and implement the new reg guide. Then they wouldn't
23 have this update just for the sake up updating the reg
24 guide.

25 MEMBER RICCARDELLA: They do update these

1 periodically.

2 MR. PALM: I mean, there's no explicit
3 just integral-based requirement to do updates. It's
4 typically based on some other --

5 MEMBER RICCARDELLA: Well, if you pull a
6 surveillance capsule.

7 MR. PALM: Right, right, or if you've done
8 a fluence evaluation for another reason, operating
9 something like that.

10 MEMBER MARCH-LEUBA: So when you do the
11 evaluation and you extrapolate for the next 10 years
12 where you expect to be. You calculate a PT for -- and
13 don't touch it.

14 MR. PALM: Yes. I mean, typically, when
15 plants do this, they will extrapolate until the end of
16 their license period of operation.

17 MEMBER MARCH-LEUBA: So in my opinion, if
18 I was to tie these phases to something, I would tie it
19 to a state; what's your fluence? If your fluence is
20 less than five times 10 to the 19th, don't touch it,
21 because if you even dare to calculate with the new
22 one, you might be better, but you might be off. And
23 if you are off, R21 (phonetic) will require you to
24 change it. So you're better off not touching it. But
25 the phase I would tie it to the state of the plant,

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1 not --

2 MR. HARDIN: There are several ways you
3 can --

4 MR. PALM: Right. I think our primary
5 message is that if the staff is to revise the reg
6 guide, we don't think an approach similar to what was
7 done in the previous revision would be necessary.

8 (Simultaneous speaking.)

9 MEMBER RICCARDELLA: They would need a
10 certain period of time to update their --

11 MR. PALM: Yes.

12 MEMBER MARCH-LEUBA: That would be abusive
13 and certainly I don't think it is necessary. And I
14 don't know think the staff, in a good environment,
15 will even dare do anything.

16 MR. PALM: Okay.

17 MEMBER MARCH-LEUBA: But I'm looking at
18 this figure. You remember it, right?

19 MR. PALM: Yes. That's the one I was
20 referring to.

21 MEMBER MARCH-LEUBA: Above five we're not
22 predicting right. And in my view, because they're
23 foreign plants, include North Korean reactors, you
24 know? When we have your sample, we will know better.
25 But right now we have to assume it's wrong.

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1 CHAIR BALLINGER: Okay. We'll go around
2 at the last, but we should now take public comments.
3 So around the room, if there's anybody in the room
4 that is a member of the public, or can claim that
5 they're members of the public and would like to make
6 a comment, please do so now.

7 Five-second rule; are you done? The
8 public line is open, I think. Open? Is there
9 anybody, any members of the public out there that
10 would like to make a comment? If there are, please
11 state your name and make your comment. I thought
12 there were three or four people on there. I guess
13 not.

14 Okay, can we close the public line then?
15 And now let's go around the table and get final
16 comments from members. I think we've kind of settled
17 on, and Chris will negotiate the path going forward
18 and everything. Walt?

19 MEMBER KIRCHNER: No further comments at
20 this time. Thank you.

21 CHAIR BALLINGER: Pete?

22 MEMBER RICCARDELLA: You know, I've seen
23 a lot of excellent work here by both the staff and
24 EPRI, and it's clear that the current correlation
25 isn't as good as it could be. But at the same time,

1 I'm understanding that changing that could be a
2 delicate licensing issue that we have to address
3 carefully.

4 CHAIR BALLINGER: Mm-hmm. Joy?

5 MEMBER REMPE: I also appreciate
6 presentations, and I think, well, I get some credit
7 for pushing to make sure this happened and we get the
8 funds early on. I'll look forward to what we do offer
9 in November. Thank you.

10 MEMBER MARCH-LEUBA: I just want to
11 emphasize two things I said before, yes, repeating
12 myself. I often say I'm a car salesman; you have to
13 do it over and over again.

14 The solution I see for the licensing
15 burden is to impose a limitation on fluence and maybe
16 chemistry. Like if you don't have potassium, or you
17 have copper less than 0.12, you don't have to do
18 anything, because the old correlation feeds perfect.

19 And if you are outside those limits, that
20 box where the staff determines that the statistics are
21 too inaccurate, then you have some time to evaluate
22 what your plan looks like. We don't want to get a
23 surprise that we're outside the limit when we get the
24 new sample 10 years from now.

25 The second thing I wanted to emphasize

1 again is, I was extremely pleased by NUREG KM 0013,
2 which makes a very systematic, logical way of
3 generating data-driven models. And it has 25 logical
4 questions; that tells you how to judge how well your
5 correlation is, and I would encourage all of you to
6 read it, because it makes the review of this data easy
7 to do. It's logical; it's step-by-step; it's
8 instructional.

9 With that, I thank you very much for your
10 talk; it was very interesting on a topic I didn't know
11 very much about.

12 CHAIR BALLINGER: Well --

13 MEMBER REMPE: Don't forget the guy in the
14 sky.

15 CHAIR BALLINGER: Oh, the guy in the sky.
16 Dave?

17 MEMBER PETTI: I don't have much to add to
18 what others said. I mean, it's clear the correlation
19 doesn't work -- so I think it's something we'll have
20 the staff pursuing technically, so that they keep
21 abreast of what's been going on out in this community.

22 One way requires a licensing change, but
23 that's sort of a different discussion. But it's worth
24 research staying abreast of all that.

25 CHAIR BALLINGER: Okay. Then I can take

1 what everybody else has said, and we've got a path
2 forward that we're going to work on.

3 For the committee, I'd like to thank you
4 guys and the staff and everybody for spending the time
5 to put this together so that we can get an
6 understanding of this.

7 We look forward to putting a lot of
8 pressure on you in the future. So we are adjourned.

9 (Whereupon, the above-entitled matter went
10 off the record at 4:17 p.m.)
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Regulatory Guide 1.99, Rev. 2

Assessment Results

Dan Widrevitz

August 22, 2019

Introduction

- This presentation summarizes a multi-year effort to thoroughly assess RG1.99 through a modern data-driven approach.
- The assessment does not address licensing basis or policy decisions.
- Discussion of next-steps and regulatory implications is not part of this assessment.

Today's Presentation

- Regulatory Guide 1.99 Background
- RT_{NDT} results
- ΔUSE results
- Credibility Criteria/Plant-Specific Data results
- Attenuation results
- Common additions
- Conclusions
- Next Steps

Today's Presentation

- Assessment focused on RG1.99, Rev. 2, as applicable to operating and new reactors.
- Assessment was not focused on “solutions” or establishing regulatory positions.

Regulatory Guide 1.99 Background

“Radiation Embrittlement of Reactor Vessel Materials”

- Rev. 2 issued May, 1988
- Provides predictive curves supporting calculation of RT_{NDT} and USE*
- Provides methods to utilize plant-specific surveillance data including “credibility criteria”
- Provides through-wall neutron attenuation formula

Regulatory Guide 1.99 Background

Regulatory Analysis for RG1.99, Rev. 2 states,

There is, however, a strong probability that revisions will continue to be made over the lifetime of the plants as more data are added around the "fringes" of the data base: high nickel materials, low copper "modern" steels, and high fluence conditions encountered in plant life extension.

Regulatory Guide 1.99 Background

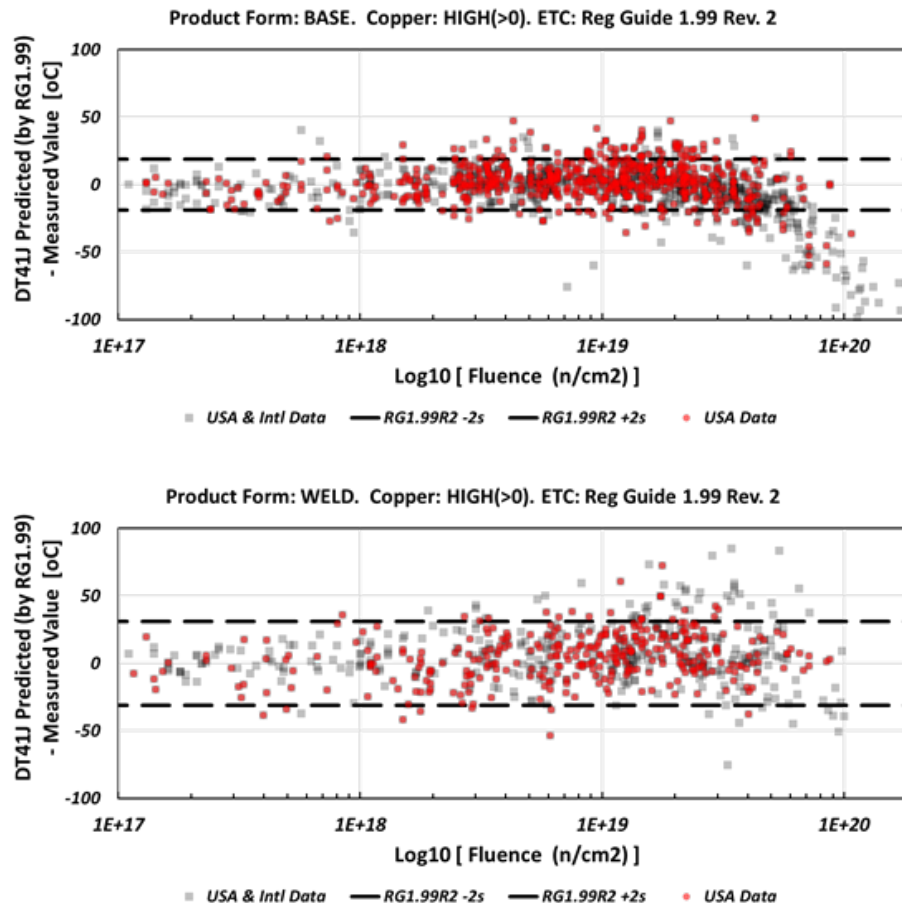
- RT_{NDT} curves fit to 177 datum. Curves are a mix of Guthrie and Odette results with “feathering” for low Cu regime.
- USE developed as upper-bound curves. Appear to have been “hand-drawn.”
- Credibility criteria and use of surveillance data have no traceable underpinnings, “engineering judgment.”
- Attenuation formula based on dpa studies.

RT_{NDT} Results

Product Form	ΔT_{41J} Data	
	PWR	BWR
Weld	509	165
Plate	499	147
Forging	377	44
SRM*	153	7
Σ	1538	363

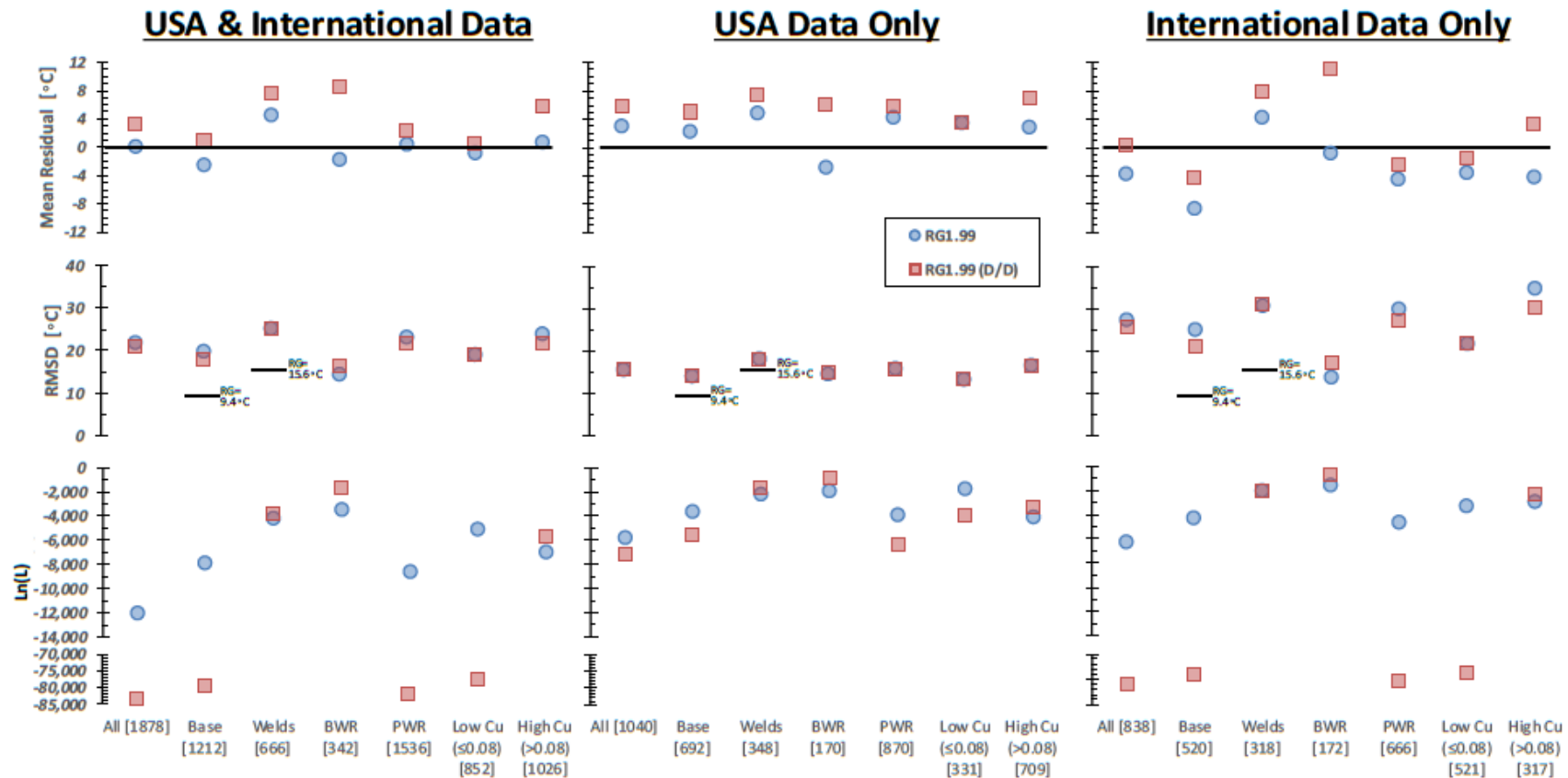
Assessment based on BASELINE dataset generated by ASTM E10.02. Dataset includes domestic and international power reactor data (~55% domestic).

RT_{NDT} Results



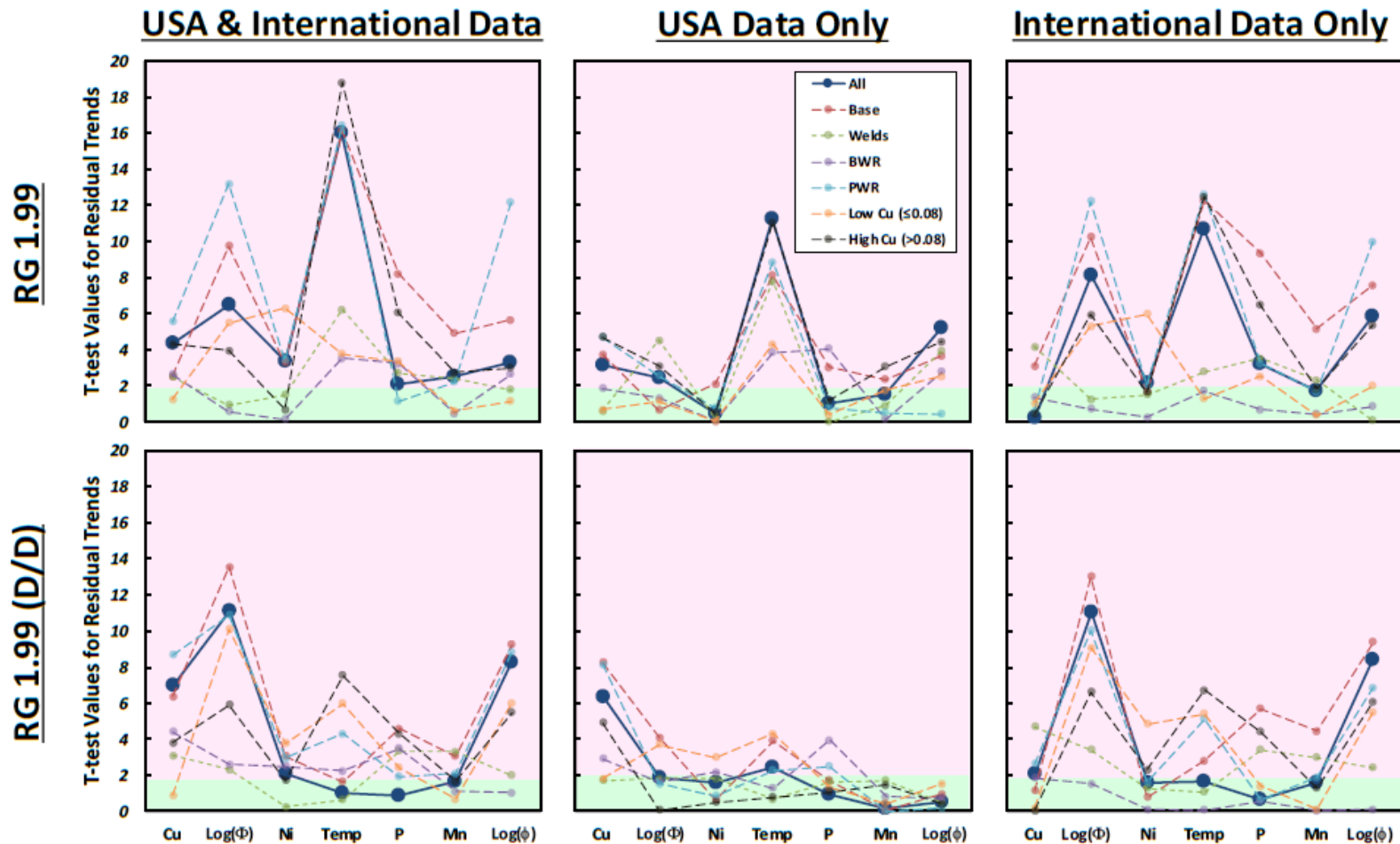
Limited weld data at high fluence precludes assessment of whether weld trends with base metals at high fluences.

RT_{NDT} Results



Good statistical behavior classically minimizes mean residual (bias), RMSD (bias and scatter), and maximizes ln(L) (commonly the log-likelihood; this means values closer to 0 are superior).

RT_{NDT} Results



For Student's T tests, a value of 1.96 indicates that 95% of the data falls within 1.96 standard deviations of the mean, which is conventionally considered an acceptable fit.

RT_{NDT} Results

Primary deficiencies:

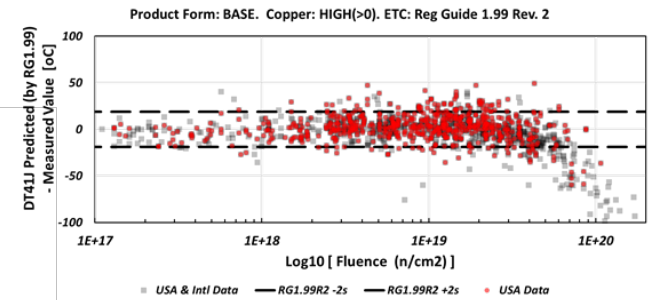
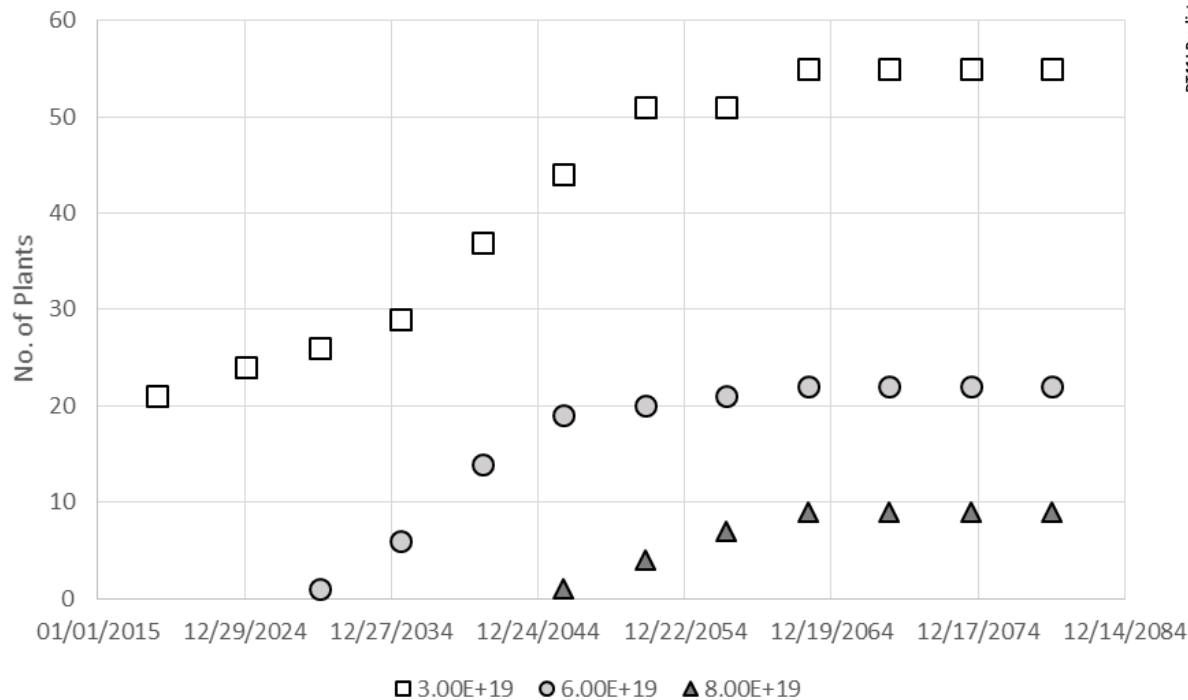
- Nonconservative high fluence results (base metals)*
- Inaccurate low Cu results

Secondary deficiencies:

- Too low stated standard deviation (margin term)
- Conservative bias in low-to-mid fluences (burden)
- Lack of temperature adjustment (inaccuracy)

* Limited weld data available at fluences near or above 1×10^{20} n/cm² (E > 1MeV)

RT_{NDT} Results



Total Number of Reactors > 3x10¹⁹ n/cm²

40 Year	60 Year	80 Year
19	41	55

Total Number of Reactors > 6x10¹⁹ n/cm²

40 Year	60 Year	80 Year
0	5	22

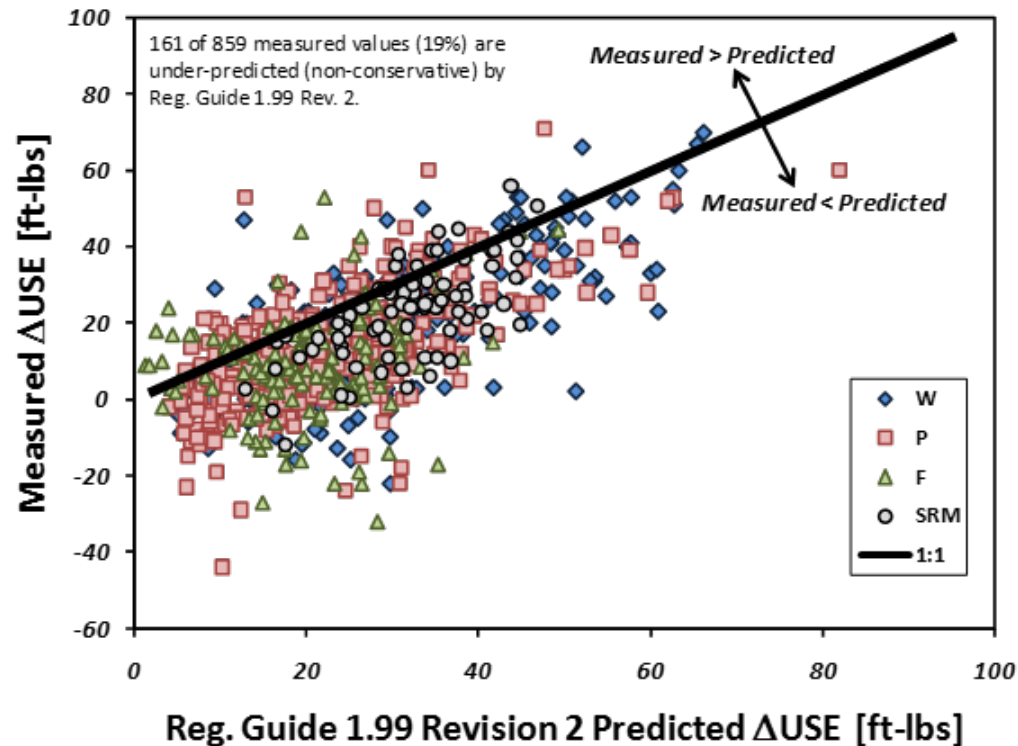
Peak ID fluences estimated from BWRVIP and MRP reports – not verified recent licensing basis values. Values represent capsule fluences “approximately” at EOL and EOLE values.

Δ USE Results

	USA & International Surveillance	Just USA Surveillance	Just International Surveillance
All	1,223	1,016	207
Weld	399	329	70
Base	824	687	137
PWR	1,068	861	207
BWR	155	155	0
Low Cu (≤ 0.08)	495	328	167
High Cu (> 0.08)	728	688	40

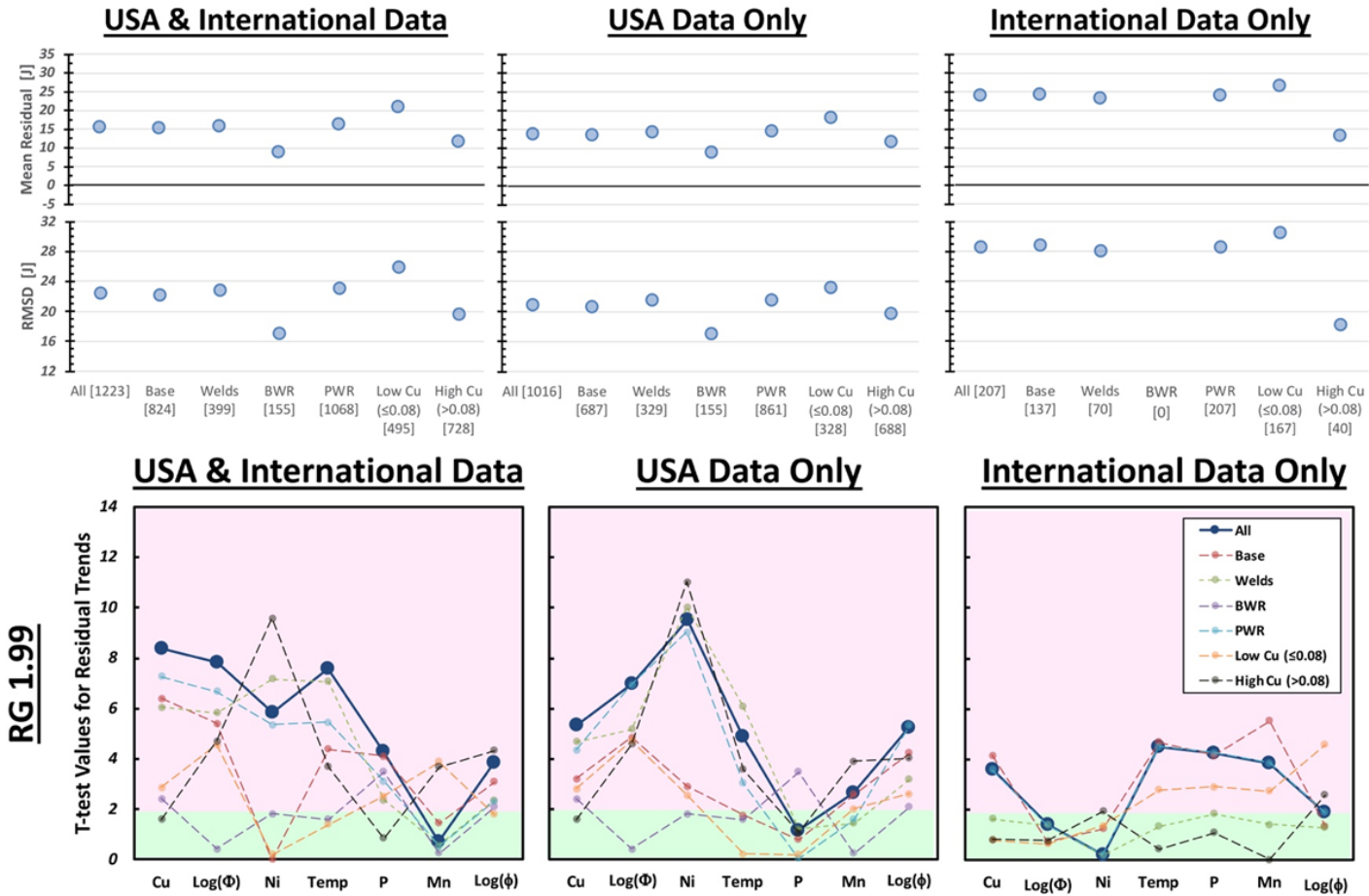
Assessment based on REAP dataset merged with properties from BASELINE. Dataset includes domestic and international power reactor data.

Δ USE Results



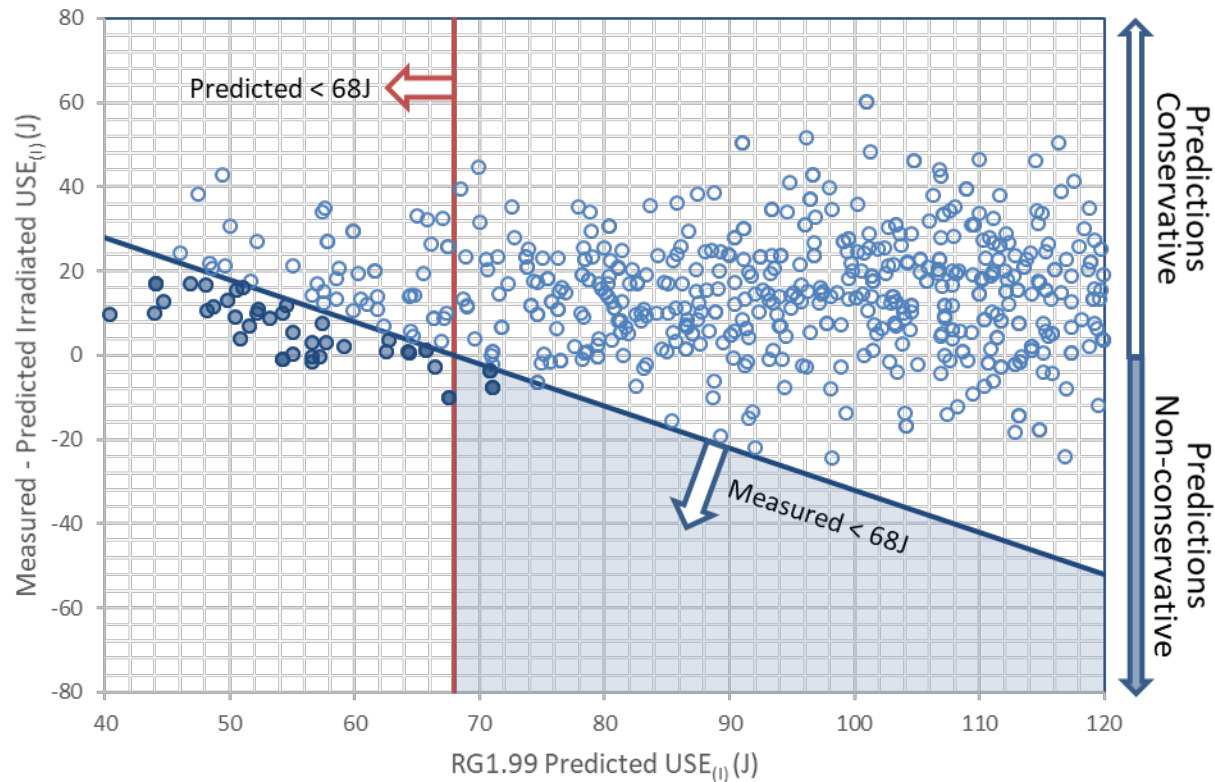
Design of USE predictions was originally intended to be upper bound.

Δ USE Results



RG1.99 USE estimate was designed to be bounding, hence positive mean residual and RMSD is to be expected.

Δ USE Results



50 ft-lb = 68J

EMA – Equivalent margin analysis.

Limited number of materials are likely to be measured below 68J (50 ft-lbs) but not have been subject of an EMA.

Δ USE Results

Primary deficiencies:

- Limited number of materials are misprojected to remain above 50 ft-lb and not trigger EMAs*
- Δ USE predictions are not bounding as originally designed

Minimal impact – the safety criteria supported by USE estimation (50 ft-lb) is known to be extremely conservative.

Credibility Criteria

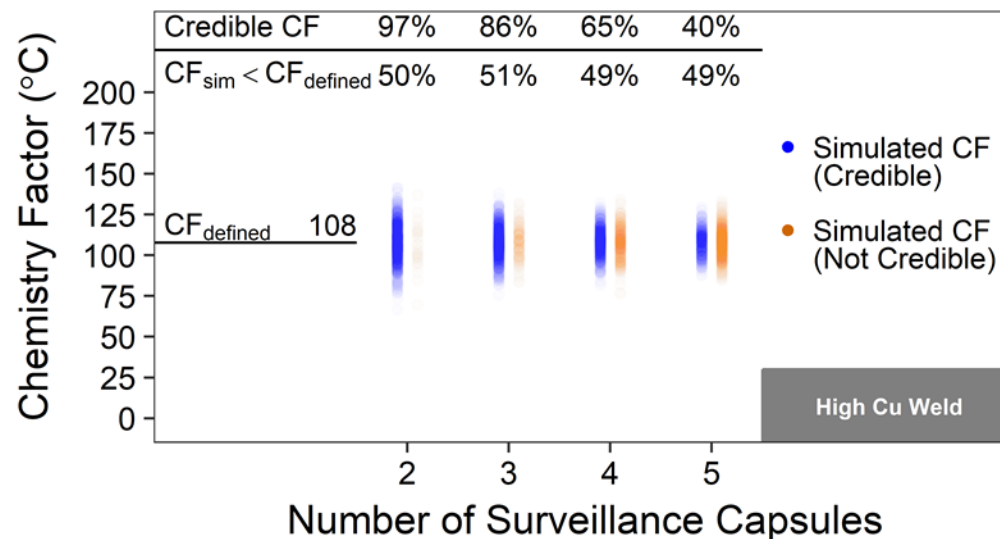
- Vague criteria open to interpretation.
- If data is not deemed credible, data is not considered.
- Criteria compare measured data to refit (chemistry factor) RG1.99 prediction results with a requirement of shape-function of RG1.99

Credibility Criteria

- Staff presentation, Wichman 1998, provided staff perspective on implementation of vague credibility criteria.
- This included that a single outlier does not invalidate a dataset.

Credibility Criteria

More data -> higher likelihood of being deemed non-credible.



- * Simulated materials have material and statistical properties as described in RG1.99, Rev.
2. Simulation rejects data for single outlier.

Credibility Criteria

Critical consequence: benefit of fitting predictions to surveillance data is nullified by credibility criteria that reject data not conforming to the shape-function of RG1.99

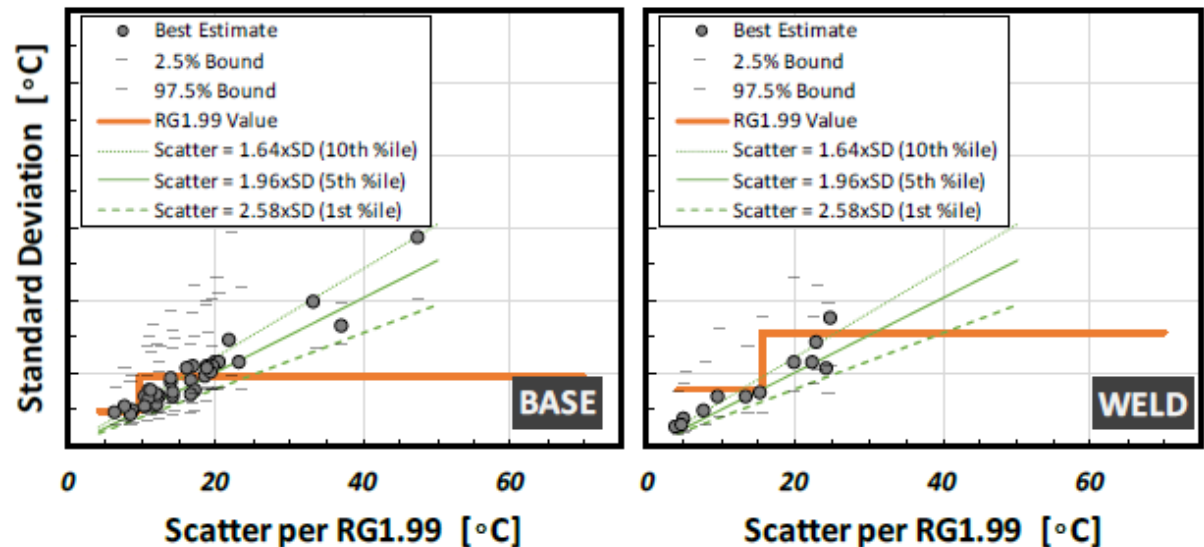
High fluence and low Cu data not expected to conform to shape function of RG1.99.

Credibility Criteria – Credible Data

If surveillance data is deemed credible, RG1.99 allows reduction in margin term.

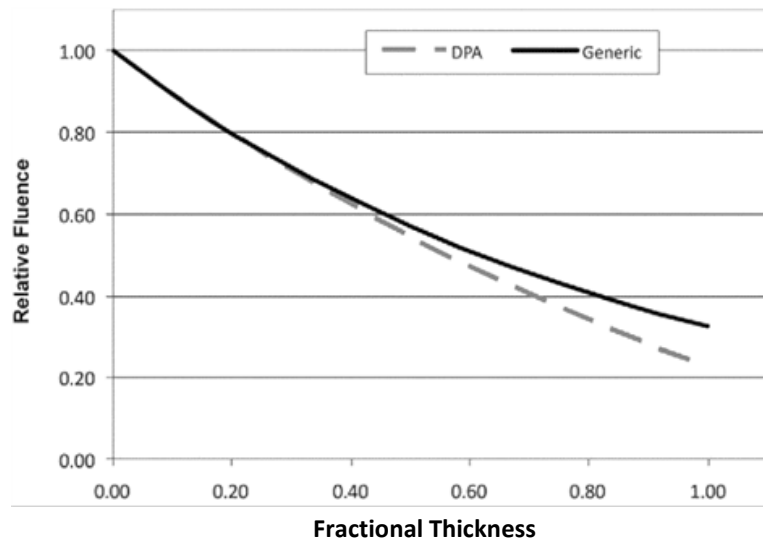
No apparent statistical basis.

Does appear to
“work” with
data.

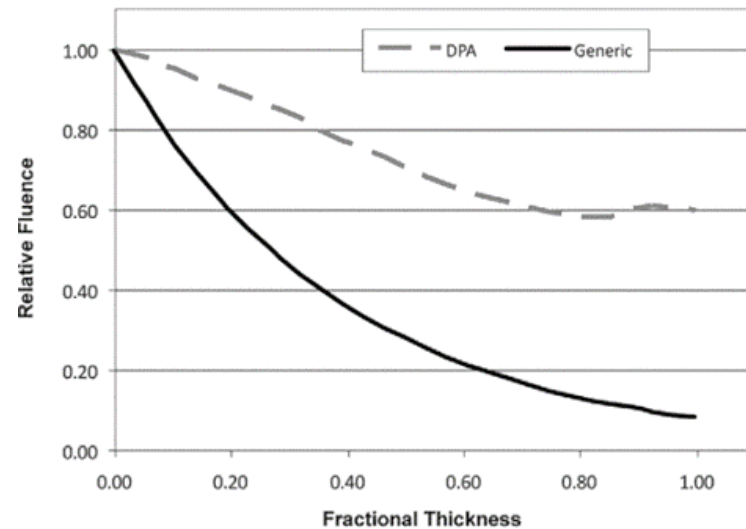


Attenuation Formula

Attenuation formula matches well to modern results. Formula *only works* for areas horizontally adjacent to the active fuel.



Geometric Beltline

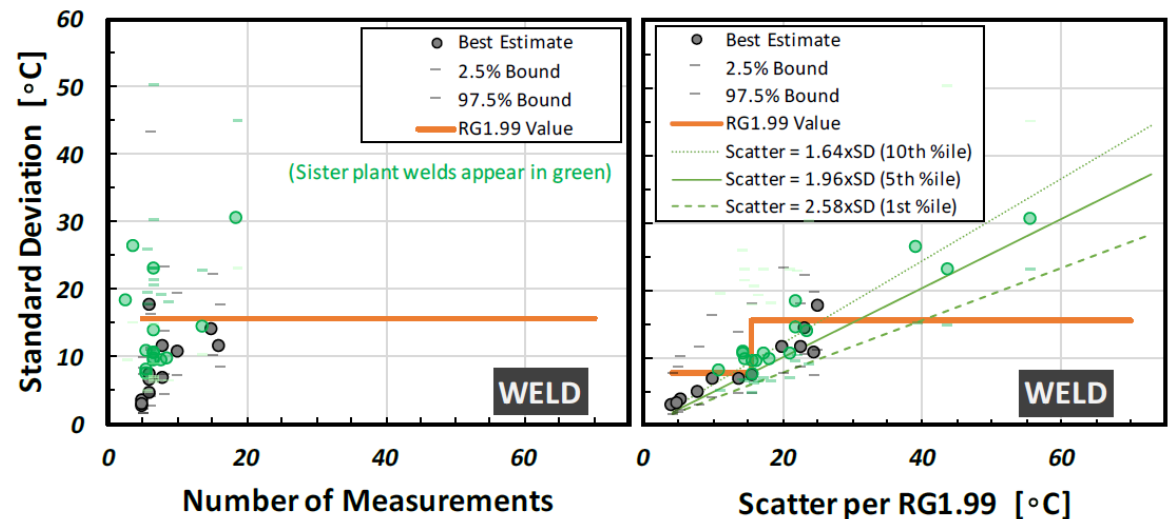


Above Core

Common Addition – Sister Plant

Data from “sister plants” may be adjusted for temperature and used as plant-specific data.

Appears to increase SD relative to plant-specific data.



Conclusions

Primary Deficiencies:

- High fluence RT_{NDT} predictions
- Credibility criteria performance
- Embrittlement trend curve shape function

Additional Deficiencies:

- Gaps currently filled by Wichman 1998 presentation*
- Statistical treatment (standard deviation, etc.)

* Implementation of credibility criteria, degree-per-degree adjustment, etc.

Conclusions

- Deficiencies exist in every aspect of the RG.
- Deficiencies become concerning for high fluence PWRs beginning in the late 2020s.

Next Steps

Working group stood up to address:

- Licensing basis impacts
- Potential solutions

EPRI Review of TLR-RES/DE/CIB-2019-2, *Assessment of the Continued Adequacy of Revision 2 of Regulatory Guide 1.99*

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Reactor Fuels**

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Introduction

- As requested by NRC, EPRI staff have reviewed TLR-RES/DE/CIB-2019-2 (hereafter, “TLR”)
- The EPRI staff contributing to the review have extensive cumulative experience in:
 - Evaluation of the effects of neutron embrittlement and other degradation mechanisms on reactor pressure vessels (RPV) steels
 - Design and/or analysis of RPV material surveillance programs, and
 - Generation of pressure-temperature limits, pressurized thermal shock (PTS) evaluations, upper shelf energy (USE) evaluations and equivalent margins analyses (EMAs)
- This presentation offers the professional opinions of EPRI staff ***only*** and does not represent an Industry position of the US utilities

Embrittlement Shift ΔT_{41J} ($\Delta T_{30 \text{ ft-lb}}$) Trend Curve

EPRI Comments on ΔT_{41J} Trend Curve Analysis

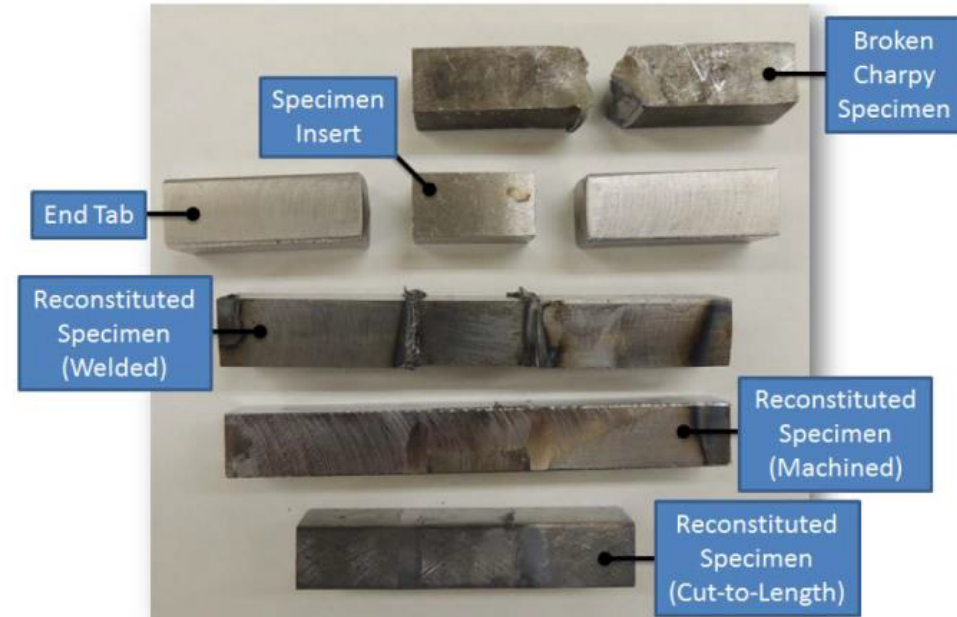
- Section 2.3 of the TLR assesses the residuals for RG1.99 ΔT_{41J} predictions relative to actual surveillance data
 - “Residual” = Predicted - Measured
- The information is largely consistent with evaluations performed by EPRI Materials Reliability Program (MRP) in ~2010-2013 to support development of industry programs to increase the amount of high-fluence surveillance data to inform future embrittlement trend correlations (ETCs)
- In the following slides, we will briefly describe the MRP programs and then discuss the evaluations of RG1.99R2 and other embrittlement trend correlations (ETCs) that were conducted as part of those programs

EPRI Comments on $\Delta T41J$ Trend Curve

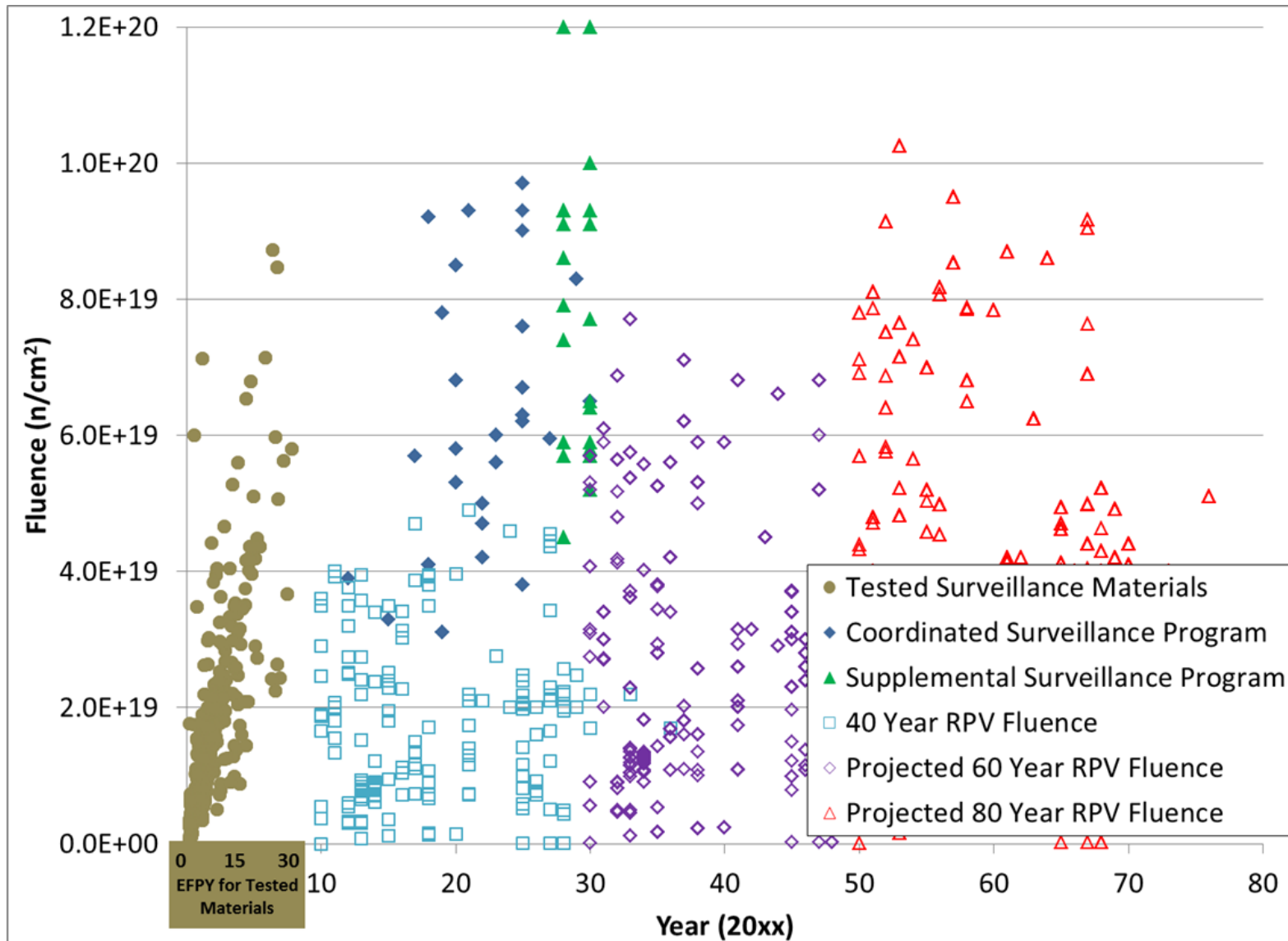
- The TLR cites two MRP programs that have been developed in the last 10 years to address a concern regarding the paucity of high-fluence PWR data sufficient to inform development of embrittlement prediction models applicable for 80 years:
 - Coordinated Reactor Vessel Surveillance Program (CRVSP) (MRP-326)
 - PWR Supplemental Surveillance Program (PSSP)
- The CRVSP was a program developed by MRP in 2011
 - All PWR surveillance capsules scheduled for future withdrawal were reviewed
 - For selected capsules, deferral of withdrawal was recommended in order to increase fluence while maintaining compliance with 10 CFR 50 Appendix H and E185-82
 - The program was successfully implemented; however, numerous high-fluence surveillance gaps were predicted to remain
 - To address the remaining gaps, MRP developed the PSSP

PWR Supplemental Surveillance Program (PSSP)

- The PSSP is a research project to design, fabricate and further irradiate two supplemental surveillance capsules containing previously-irradiated PWR materials
 - Previously-irradiated and tested Charpy V-notch specimen halves were reconstituted (per ASTM E1253-13)
 - These specimens are being re-irradiated for ~10 years, adding ~3.5 E+19 n/cm²) to each material's previous fluence
 - The PSSP will obtain high fluence toughness data on 27 unique RPV materials
 - The capsules were inserted in Farley 1 (2016) and Shearon Harris (2018) and will be withdrawn and tested in 2027/2028
 - Use of 2 plants permits data collection at 2 irradiation temperatures



Future Availability of High-Fluence Surveillance Data Relative to RPV Material Predicted Fluence in Time



Updated figure
by J. Brian Hall,
WEC

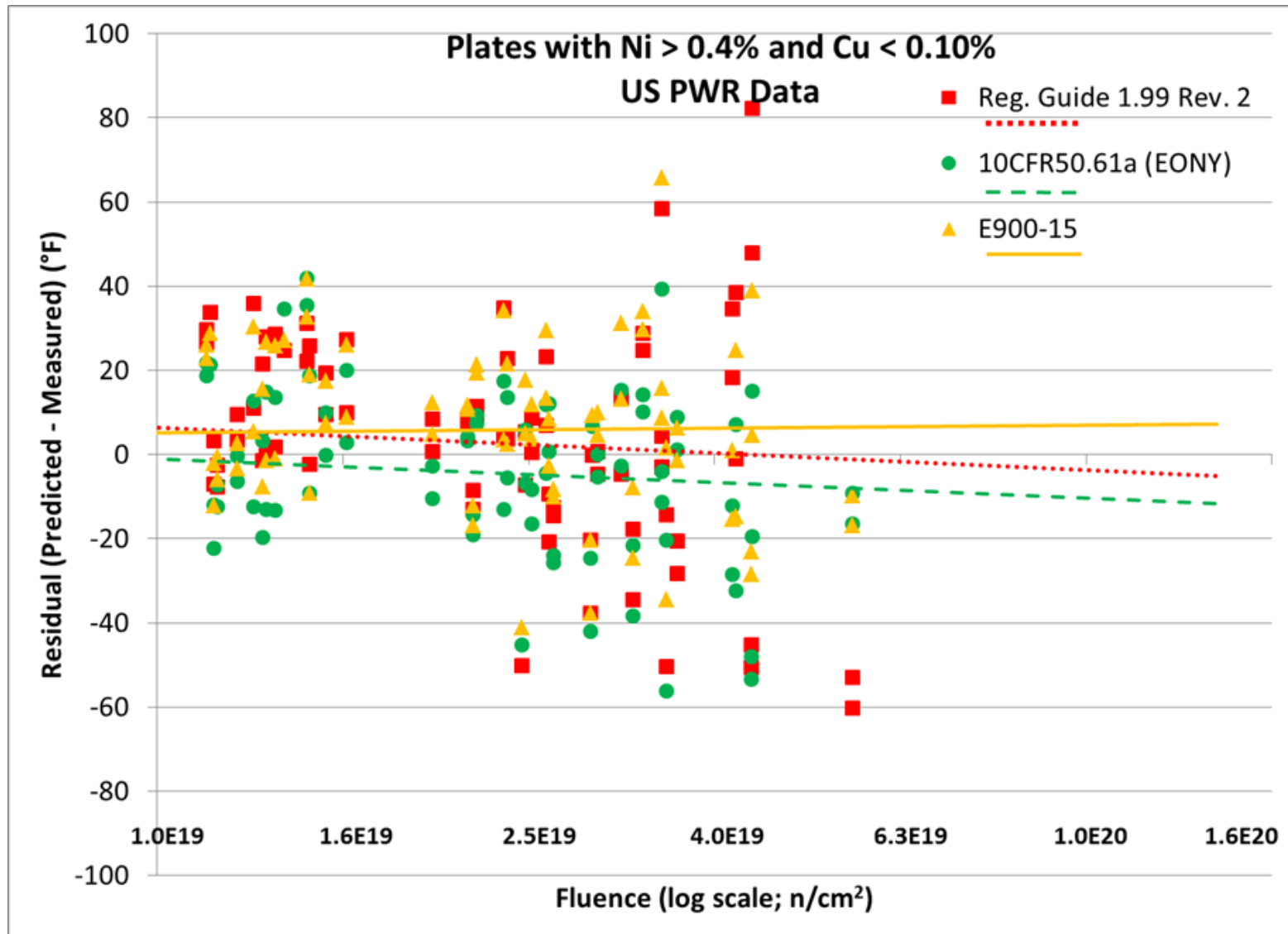
Material Selection Process for the PSSP

- To select specific materials for the PSSP capsules:
 - All U.S. RPV surveillance materials were grouped according to product form: plates, forgings, and welds. Those groups were then further sub-divided according to chemistry (e.g., high-Cu, Low-Cu, high-Ni, low-Ni, etc.)
 - Each material group was then evaluated to determine whether materials from that group should be included in the PSSP
 - One metric was how well various ETCs predicted the embrittlement of the data for each group
 - Poorly-predicted groups were given higher priority for inclusion of those materials in the PSSP
 - The results are documented in MRP-364 (not publicly available) and PVP2013-97039 (available)

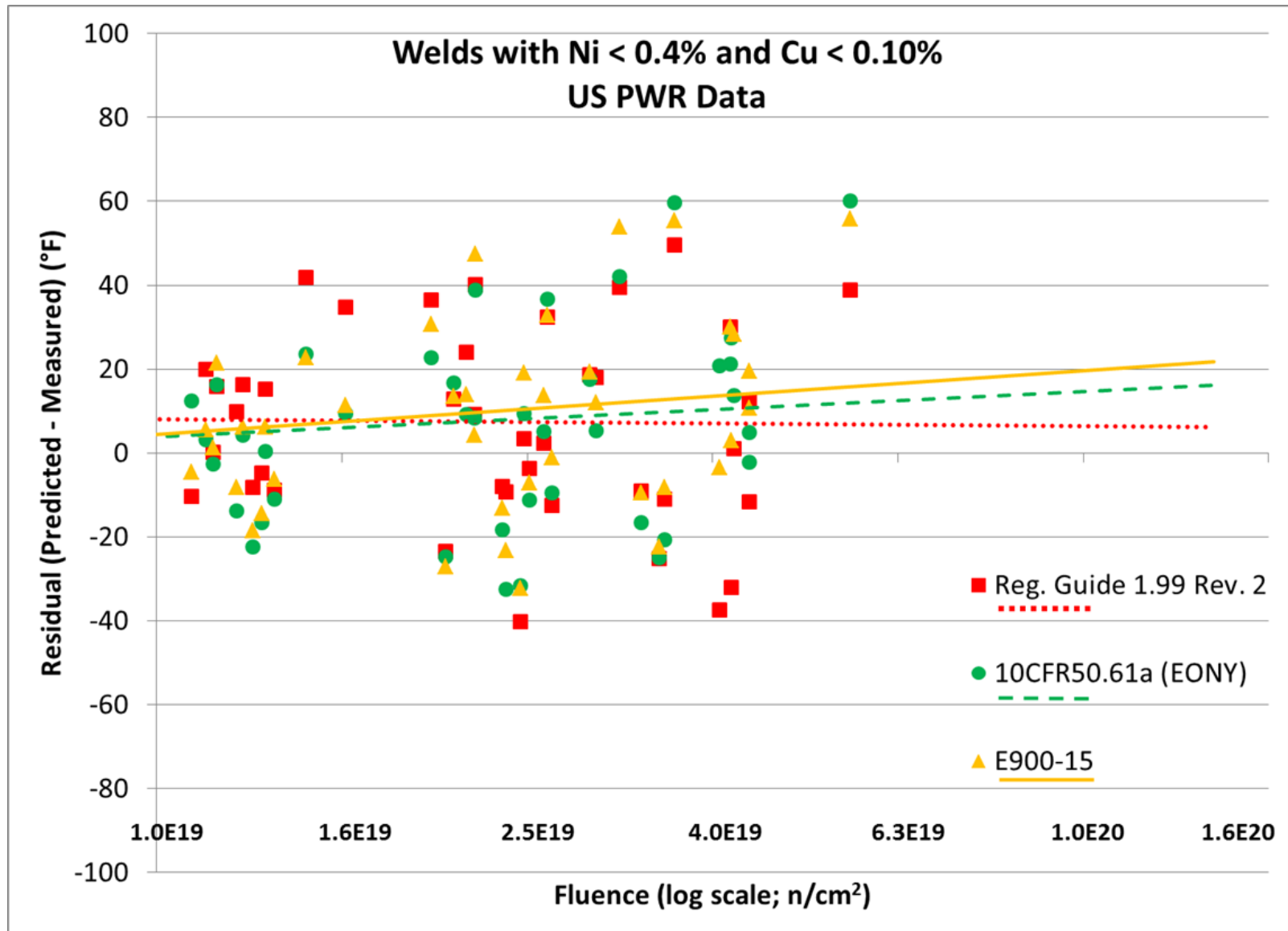
Existing U.S. Power Reactor Surveillance Data

- U.S. PWR surveillance database (as of ~2012) was compared with common prediction models
 - Regulatory Guide 1.99, Rev. 2 [177 surveillance data values were used to develop this 1980s model]
 - EONY [based on approximately 750 power reactor surveillance data values from about fourteen years ago] – as used in Alternate PTS Rule (10 CFR 50.61a)
 - WR-C(5), Rev. 1 – see Kirk, ASTM STP-1547 (2013)
 - More recently, ASTM E900-15 [which is based on an extensive world-wide power reactor database] was assessed for a few material groups, after its adoption
- Selected plots are shown in the following slides as examples
 - The data used here only includes US PWR irradiations
 - No model alloys
 - No Standard Reference Materials (SRMs)
 - Only 41J (30 ft-lb) index temperature shift measurements

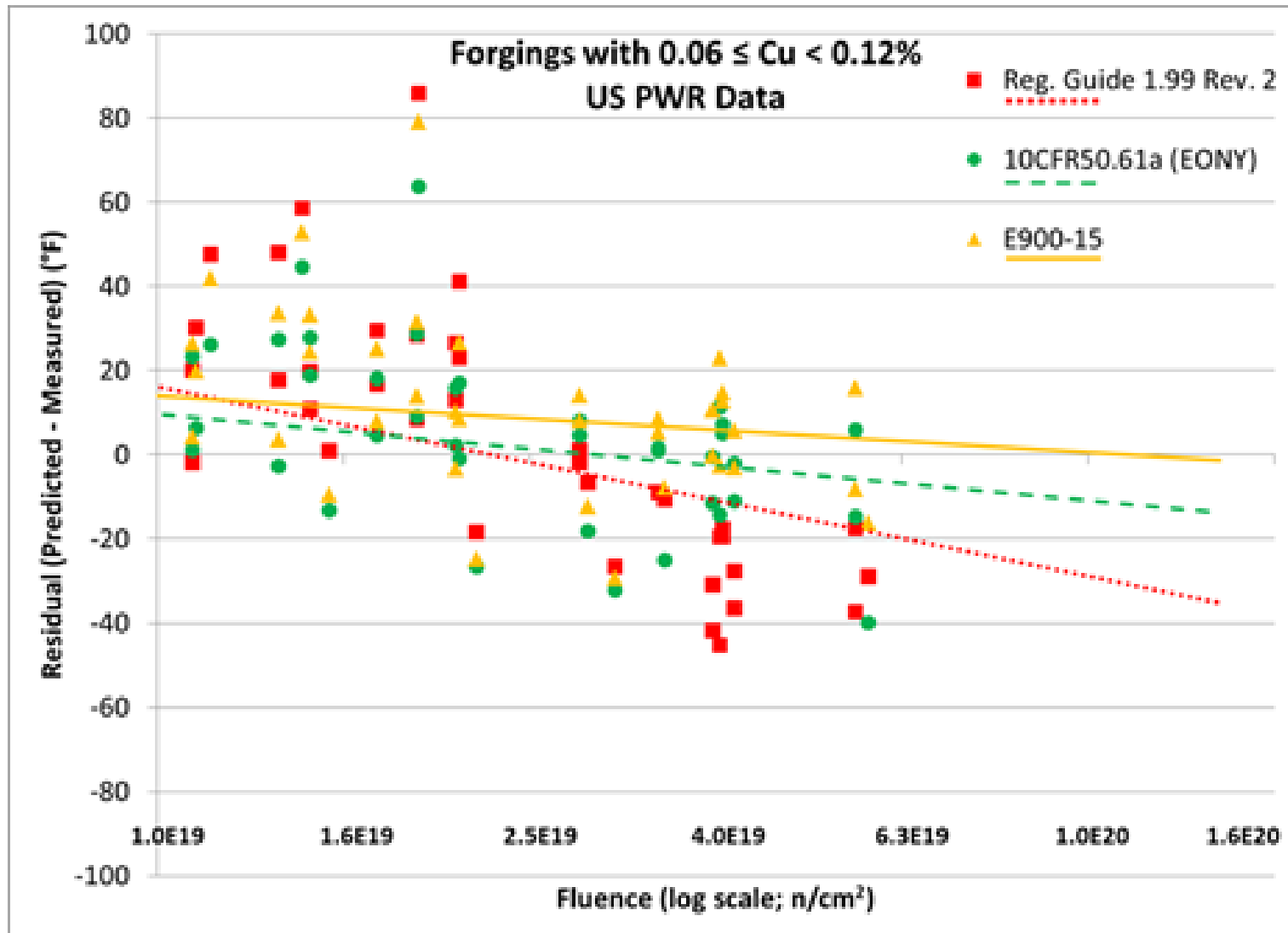
Example – Comparison of ETCs for Low Cu / Ni-added Plates



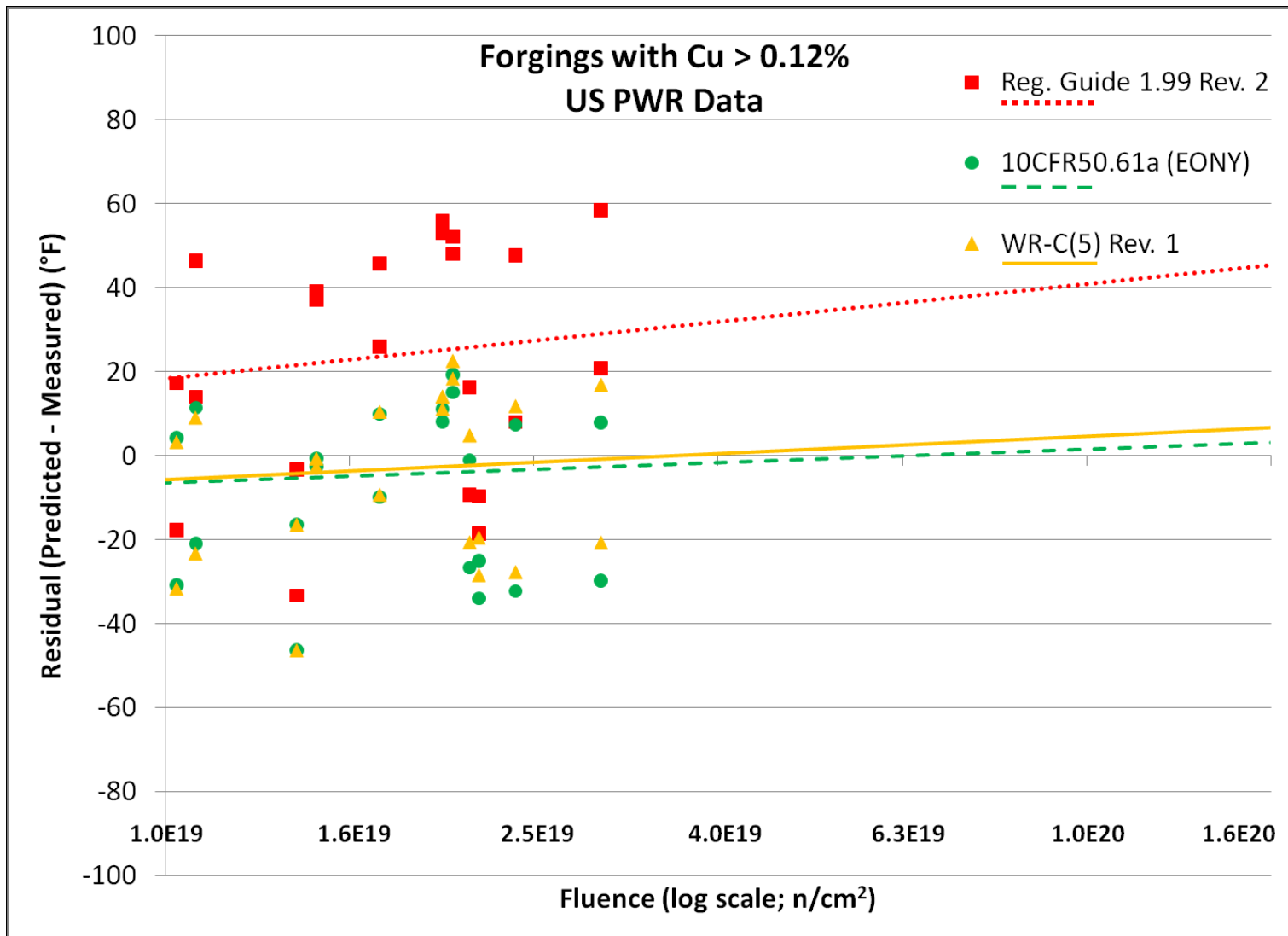
Example – Comparison of ETCs for Low-Cu, Low-Ni Welds



Example – Comparison of ETCs for Medium Cu Forgings



Example – Comparison of ETCs for High Cu Forgings



Summary of MRP Analyses of Surveillance Data vs. ETCs

- In 2013, MRP assessed the residuals for U.S. PWR surveillance data compared to several ETCs
- The objective was to inform selection of materials for inclusion in the PSSP capsules
- The mean trends vary significantly as a function of product form and chemistry
- Overall, scatter in the RG1.99R2 residuals increases significantly with increasing fluence

Form/Ni Division	Cu Group	RG 1.99, Rev. 2 Fit	EONY Fit
Plates SA-302BM, SA-533B1	< 0.10	O/U	—
	0.10–0.17	— /U	—
	> 0.17	—	U
Plates SA-302B	All	—	—
Forgings SA-508	< 0.06	—/U	—/U
	0.06–0.12	O/U	—
	> 0.12	O	—
Welds Ni > 0.4%	< 0.10	O	O
	0.10–0.23	—	—
	>0.23	O	—
Welds Ni < 0.4%	< 0.10	—	—
	0.10–0.23	O/—	O
	>0.23	O	—

O = Overpredicts; U = Under-predicts;
 “—” = Reasonable prediction (>1E19 n/cm²)
 “/” indicates a difference <3E19 n/cm² versus >3E19 n/cm²

Comments on TLR Section 2 (1 of 2)

- Section 2.5 of the TLR states, “Not all plants use the RG1.99 ΔT_{41J} trend curve directly as many supplement it with surveillance data or other adjustments such as degree-per-degree. For these plants, deficiencies in the trend curve are not expected to correlate directly to potential deficiencies in licensing bases.”
- EPRI Comment #1:
 - This statement understates use of RG1.99R2 in the fleet. **All plants use RG1.99 directly for** any materials where surveillance data does not exist – which, for any given RPV, are ***most of the RPV materials***

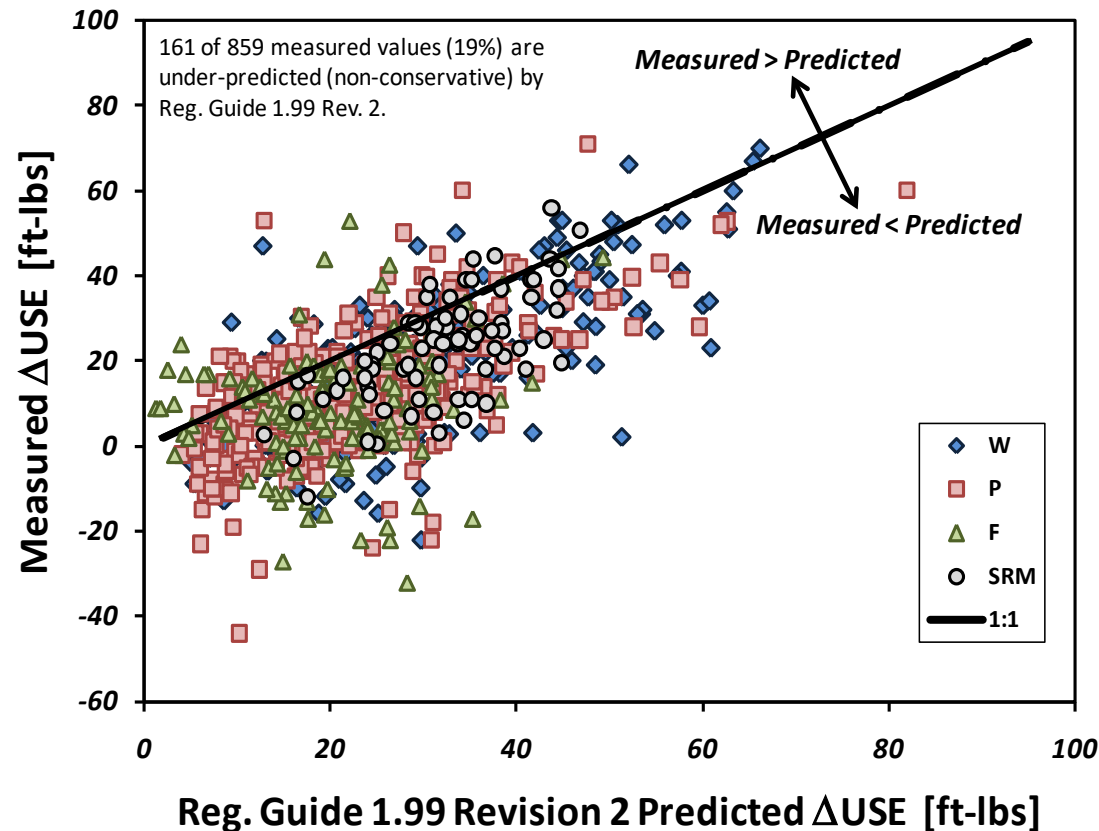
Comments on TLR Section 2 (2 of 2)

- EPRI Comment #2: Currently, to apply weld surveillance data for evaluation of vessel welds (matching heats) when the chemistry of the surveillance and vessel welds differ, the Chemistry Factor (CF) from RG1.99R2 Table 1 is used in a ratio procedure. If a new approach is adopted that no longer defines/uses a Chemistry Factor (CF), it will be necessary to develop alternate guidance for adjusting shift (ΔT_{41J}) to account for chemistry differences
- EPRI Comment #3: The TLR references the Wickman-Hiser-Mitchell slides (1998) but does not mention that the same guidance (in summary form) is also documented in NUREG-1511, Supplement 2, Section 2.3

Charpy Upper-Shelf Energy Decrease (ΔUSE) Trend Curve

NRC Research USE Prediction Method

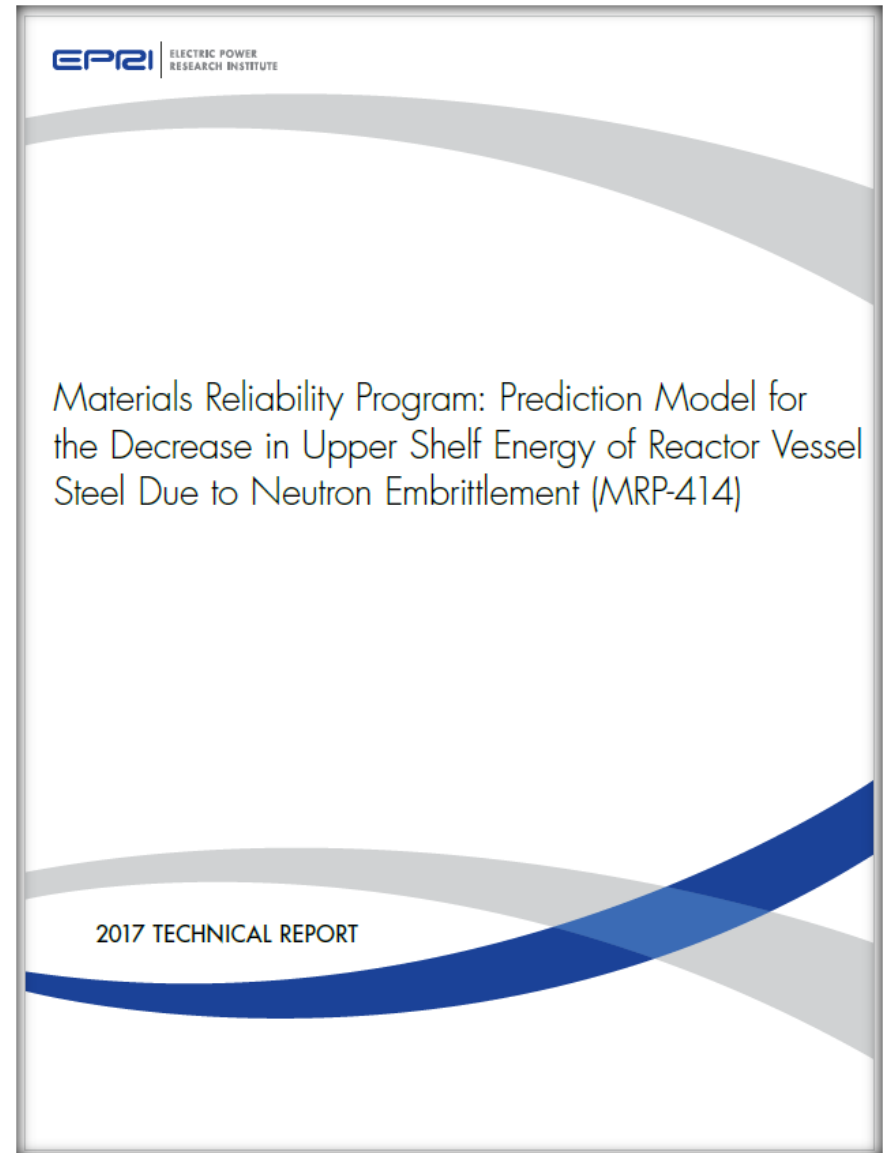
- According to NRC analysis of surveillance data, 19% of data are under-predicted by current RG1.99R2 prediction method for USE decrease
 - Only a 1.3σ bound
- NRC Research developed a new prediction method “UNM-6” to achieve 2σ bound [Kirk 2010, referenced in the TLR]
- MRP was concerned that the new method [Kirk 2010] may unfairly penalize non-Linde 80 weld materials and cause significantly more materials to fall below a USE of 68J (50 ft-lbs)



Source of figure: Kirk, USNRC

MRP Project for USE

- In 2016, MRP conducted a research project to develop an updated prediction method for USE decrease
- Final report was published in July 2017:
 - *Materials Reliability Program: Prediction Model for the Decrease in Upper Shelf Energy of Reactor Vessel Steel Due to Neutron Embrittlement (MRP-414)*. EPRI, Palo Alto, CA: 2017. 3002010330.
 - Not yet publicly available
 - Also presented in PVP2017-65317 (publicly available)



Overview of MRP USE Prediction Model Project

- An extensive USE database was assembled
 - >1500 irradiated material USE change measurements (LWR surveillance data only) from US, Korea, Germany, Brazil, Spain, Mexico, Sweden, France
 - After screening, 1,177 data used for modeling
- Two types of best-estimate fit models were investigated
 - One using transition temperature shift (TTS – e.g., ΔT_{41J}) predicted by ASTM E900-15 as the primary input parameter
 - One type not using TTS
- To reduce complexity, MRP-414 recommended the model that did not use the E900-15 TTS as a primary input parameter

Results from MRP-414 USE Prediction Model

- MRP assessed the impact of the model recommended in MRP-414 on the operating PWR fleet
 - USE at the end-of-license for 60 & 80 years operation was estimated for 65 PWR plants
 - The impact on the number of operating US PWRs which have a decrease in USE below 50 ft-lbs (30 PWRs, 92 material heats) is similar to RG1.99R2 (30 PWRs, 82 material heats) and less than the UNM-6 model previously published by NRC Research
- MRP-414 provides an USE prediction model that bounds 2σ of the data but has negligible increase on the total number of plants that will need to perform an EMA (as compared to RG1.99R2)
- EPRI Comment #4: If NRC pursues revision of the RG1.99R2 USE decrease prediction model, we recommend NRC consider the work that was performed in MRP-414 / PVP2017-65317

Additional Comments on Section 3 of the TLR (1 of 2)

- Section 3.5 states: “The RG1.99 predictions of Δ USE contain conservative bias, significant uncertainty, and significant residuals relative to input variables. The impact on the operating fleet and new reactors that may be constructed is unclear as two acceptance paths exist (i.e., maintaining USE greater than 68J [50 ft-lbs] during licensed operation, or conducting an EMA). Further work is needed to evaluate the regulatory significance of the current 68J criteria and to determine if it should be retained, modified, or eliminated.”
- EPRI Comment #5: Generally agree, but we note that the requirement for minimum USE is established in 10CFR50 Appendix G, not RG1.99R2. Therefore, the last two options (“modified, or eliminated”) imply a recommendation for rulemaking for revision of 10 CFR 50 Appendix G
 - We request clarification regarding NRC intent for revision of Appendix G

Additional Comments on Section 3 of the TLR (2 of 2)

- In Section 3.4 “Fleet Impact” [of USE trend curve evaluation], the TLR states:
 - “For this assessment, a preliminary estimate of the number of reactors that may fail the 68J (50 ft-lbs) criterion if measured but are not predicted to do so was conducted. Seven reactors were identified [using a modern trend curve, “Kirk2010”] (a further four reactors identified plan to cease operation imminently as of 2019). Of these, three had implemented equivalent margins analyses. The remaining four all had approved USE calculations from license renewal applications with staff verifying their calculations. [These plants warrant further review.](#)” [*emphasis added*]
- EPRI Comment #6: [This statement/conclusion](#) should be clarified or revised. It implies an inadequacy in the existing USE calculations and could be interpreted as a regulatory challenge questioning plant licensing bases
 - As acknowledged in the TLR, the USE calculations for those plants are based on current regulations and existing NRC guidance for the evaluation of USE
 - Therefore, until NRC revises its guidance, the TLR lacks a technical justification for questioning the licensing basis or recommending “further review” of plants that have approved USE calculations – especially when verified by NRC staff

Credibility Criteria and Use of Credible Surveillance Data

Credibility Criteria and Use of Credible Surveillance Data

- TLR Section 4.1 (page 21) states the following:
 - “Should the data be deemed non-credible, the user is directed to discard the chemistry factor refit losing what may be a superior data-based fit of the RG1.99 trend curve.”
- EPRI Comment #7: While this statement is consistent with the RG as written, it is not consistent with how NRC has *implemented* the guidance
 - If a fitted CF has been calculated from the non-credible surveillance data and it is **higher** than the table-based CF from the RG, the NRC has required the higher CF to be used for calculation of Adjusted Reference Temperature (ART) or RT_{PTS} . Furthermore, in that case the NRC has required the **full** margin term to be used
 - This is specifically documented as Case 3 of the Wickman-Hiser-Mitchell slides (e.g., “*Noncredible surveillance data from the plant to be evaluated and Table CF is nonconservative*”)

Neutron Fluence Attenuation

Attenuation of Neutron Embrittlement in Cylindrical Shell

- MRP has sponsored testing on the subject of attenuation:
 - *Materials Reliability Program: Static Tensile Testing of a Pressure Vessel Steel Irradiated to Assess Through-Wall Attenuation of Radiation Embrittlement (MRP-333)*. EPRI, Palo Alto, CA: 2012. 1024798. (publicly available)
 - Also: MRP-203, MRP-243, and MRP-277 (publicly available)
 - The paper referenced in the TLR (“Server 2010”) is a summary based on the MRP reports listed above
- This research supported the conclusions of the TLR regarding attenuation

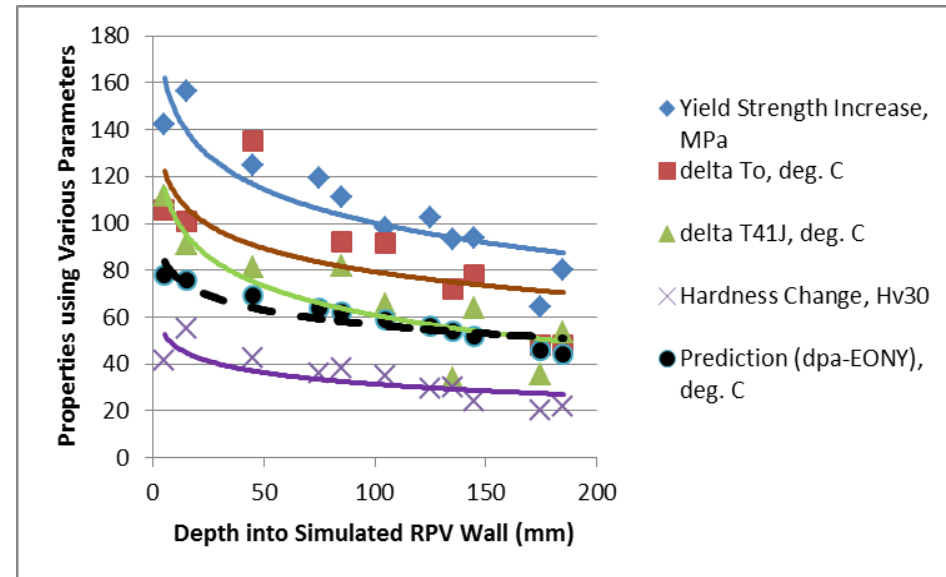
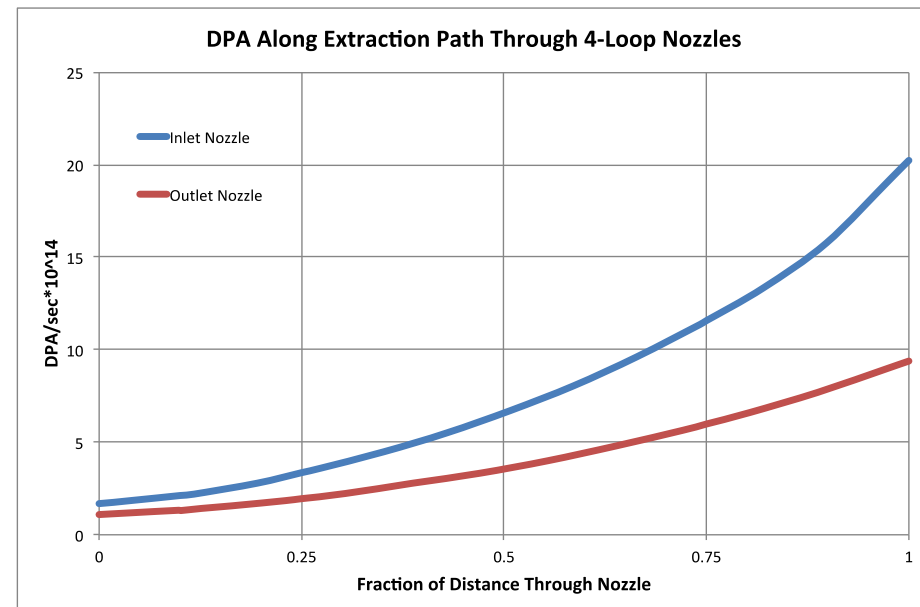
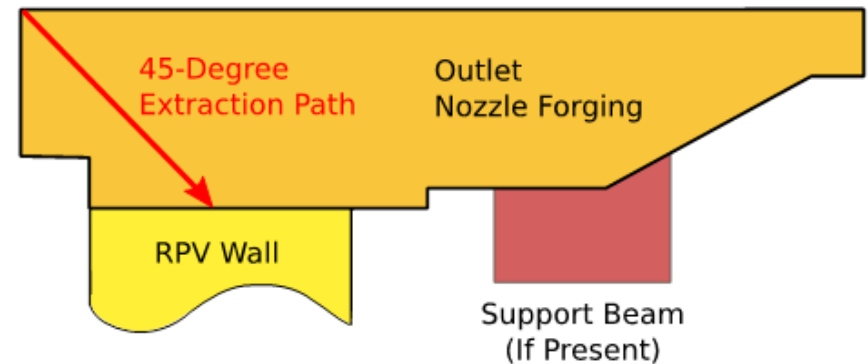


Figure 6-1 from MRP-333. Comparison of Various Mechanical Property Changes Attenuated through the RPV Wall Including the Predicted Charpy Transition Temperature Shift using dpa-adjusted Fluence and EONY Correlation.

Attenuation of Neutron Embrittlement in Nozzles

- MRP also conducted analysis of neutron attenuation in PWR nozzles:
 - *Materials Reliability Program: Fluence Attenuation Profile in the PWR Nozzle Shell Course (Inlet/Outlet Nozzles) (MRP-345).* EPRI, Palo Alto, CA: 2012. 1025157. (publicly available)
- This research also supports the conclusions of the TLR that the RG attenuation formula is not applicable in the extended beltline/nozzle region because the peak dpa rate occurs on the outer surface of the nozzle forging, in the cavity region



New, On-going Research on Neutron Attenuation

- Experiments on fluence attenuation in the cylindrical shell are continuing as part of the current DOE LWRSP testing program on the decommissioned Zion-1 RPV beltline
 - [Sokolov et al., PVP2019-93801, “Preliminary Characterization of RPV Materials Harvested from the Decommissioned Zion Unit 1 Nuclear Power Plant,” Technical Presentation only]
- EPRI Comment #8: The results of through-thickness toughness measurements from decommissioned Zion RPV material may have implications for treatment of neutron attenuation effects
 - The results from the testing of the through-thickness properties of the Zion RPV wall should be finalized, understood, and appropriately considered in development of future guidance on accounting for the effects of neutron attenuation

Common Additions to RG1.99

Common Additions to RG1.99

- The TLR discusses and analyzes the use of sister plant data.
 - EPRI Comment #9: “Sister plant data” is, to some extent, a misnomer and a concept not well defined. In practice, it is “matching heat number data.” The reality is that data from surveillance materials with heat numbers that match vessel material heat numbers are considered when evaluating vessel materials – whether or not the data originate from a “sister plant”
- The TLR states that “Consequently, the addition of sister plant data increases the likelihood that plant-specific data will be rejected.” and... “...Consequently, the inclusion of sister plant data will increase the likelihood that a data-set will be deemed non-credible.”
 - EPRI Comment #10: It should be noted that in a few high profile instances it has been very helpful to have sister plant data. In many cases, the data has benefited more than not, especially for critical materials

Comments about Implementation of Possible Future Revisions to RG1.99

Implementation of Future RG Revisions

- The adoption of new guidance regarding prediction of the effects of embrittlement will have significant impact on all operating plants (and international plants that use RG1.99)
 - P-T curves, Low Temperature Overpressure (LTOP) setpoints, etc.
- The last update of RG1.99 (1988) was introduced with onerous requirements for quick impact assessment and adoption (Generic Letter 88-10)
- While that may have been justified due to perceived safety concerns in 1988 (due to a general lack of surveillance data and the planned adoption of the new embrittlement correlation into the PTS Rule), the data presented in the TLR show that few plants will approach the fluences at which the potential nonconservatisms of RG1.99R2 is a concern (e.g., $6E+19$) before 2028
- EPRI Comment #11: The data support a ***phased implementation*** of the next revision to RG1.99, to enable plants to adopt the guidance during normal updates of operating limits and minimize unnecessary burden

EPRI Comments on TLR's *Conclusions and Recommendations*

Conclusions and Recommendations

- The conclusions of the TLR are succinct and their technical bases are thoroughly documented
 - Exception: The comment that 4 plants need further USE review
- The recommendations of the TLR are reasonably supported by the analyses presented and are generally consistent with EPRI research
- EPRI research on USE prediction models is available for consideration should NRC revise the RG USE decrease model
- A new, high-fluence dataset will become available from the PSSP in 2028-30 that could be used in a future validation of a revised RG and to inform development of future ETCs
- The data and analyses support a *phased* implementation of any revision to RG1.99R2 to **minimize unnecessary burden on the operating fleet**



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