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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

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 NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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SUBCOMMITTEE ON METALLURGY AND REACTOR FUELS

+ + + + +

WEDNESDAY

NOVEMBER 16, 2016

+ + + + +

ROCKVILLE, MARYLAND

+ + + + +

The Subcommittee met at the Nuclear
 Regulatory Commission, Two White Flint North, Room
 T2B1, 11545 Rockville Pike, at 8:30 a.m., Matthew
 Sunseri, Chairman, presiding.

COMMITTEE MEMBERS:

MATTHEW W. SUNSERI, Chairman

RONALD G. BALLINGER, Member

WALTER L. KIRCHNER, Member

DANA A. POWERS, Member

PETER RICCARDELLA, Member

GORDON R. SKILLMAN, Member

JOHN W. STETKAR, Member

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DESIGNATED FEDERAL OFFICIAL:

CHRIS BROWN

ALSO PRESENT:

PAUL BESSETTE, Morgan Lewis

WILLIAM BURTON, NRR

GANESH CHERUVENKI, NRR

DIANE CURRAN, Riverkeeper

DAVID DIJAMCO, NRR

C.J. FONG, NRR

ALLEN HISER, NRR

MATTHEW HISER, RES

GREGORY KOLCUM, R-IV

MARVIN LEWIS (present via telephone)

SIVA LINGAM, NRR

HEATHER MALIKOWSKI, Exelon

CAROL NOVE, RES

JEFFREY POEHLER, NRR

MARY JANE ROSS-LEE, NRR

BERNIE RUDELL, Exelon

DAVID RUDLAND, NRR

BALWANT SINGAL, NRR

DONG WEAVER, Westinghouse

BRYAN WILSON, Westinghouse

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P R O C E E D I N G S

8:31 a.m.

CHAIRMAN SUNSERI: The meeting is now called to order. This is a meeting of the Metallurgy and Reactor Fuel Subcommittee, the Advisory Committee on Reactor Safeguards.

I am Matt Sunseri, chairman for this subcommittee.

ACRS members in attendance today are Ron Ballinger, Pete Riccardella, Dick Skillman, Dana Powers, John Stetkar, Walt Kirchner.

Christopher Brown is the Designated Federal Official for this meeting.

The purpose of today's meeting is for the subcommittee to receive a briefing from the NRC staff and industry regarding recent operating experience with baffle-former bolt degradation. In particular, discussions on the design, functions and materials of PWR internals, baffle-former assembly, consequences of baffle-former bolt degradation, history of baffle-former bolt degradation, factors influencing baffle-former bolt degradation, bolt inspection replacement, root cause analysis results and industry response.

The rules for participation in today's

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1 meeting were announced in the Federal Register on
2 November 1, 2016. The meeting was announced as an
3 open/closed to public. A portion of this meeting
4 will be closed in order, may be closed in order to
5 discuss and protect information designated as
6 proprietary pursuant to 5 U.S.C. 552b(c) (4).

7 No requests for making a statement to
8 the subcommittee has been received from the public.

9 A transcript of the meeting is being
10 kept and will be made available as stated in the
11 Federal Register notice. Therefore, we request
12 that participants in this meeting use the
13 microphones located throughout the meeting room
14 when addressing the subcommittee. Participants
15 should first identify themselves and speak with
16 sufficient clarity and volume so that they can be
17 readily heard.

18 We have one bridge line established for
19 interested members of the public to listen in. The
20 bridge number and password were published in the
21 agenda posted on the NRC public website.

22 To minimize disturbance, this public
23 line will be kept in a listen-in only mode. The
24 public will have the opportunity to make a
25 statement or provide comments at a designated time

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1 towards the end of the meeting.

2 I request that meeting attendees and
3 participants now silence their cell phones and
4 other electronic devices.

5 Dr. Riccardella has co-authored a paper
6 on the subject matter that presents a methodology
7 for evaluating the probability of baffle-former
8 bolt cracking for pressurized water reactors. This
9 methodology recently was used as part of an EPRI
10 MRP program to address new industry findings. Dr.
11 Riccardella will not participate in matters related
12 to technical areas of his past contributions.

13 I now invite M.J. Ross-Lee, Deputy
14 Director of Engineering in NRR to introduce the
15 presenters and start the briefing. M.J.

16 MS. ROSS-LEE: Good morning. So yes, I
17 am M.J. Ross-Lee. I'm the current Deputy Director
18 of Division of Engineering, Office of Nuclear
19 Reactor Regulation. We are here to present to the
20 subcommittee. I think we'll touch on all the parts
21 as previously introduced, talk about baffle-former
22 bolts, what they are, what they do, some past
23 operating experience, current operating experience,
24 what we've done, our path forward, and what we plan
25 to do with those.

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1 Today's presenter is a member of my
2 staff, Jeff Poehler. He is a materials engineers
3 and he will be taking us through the presentation
4 today.

5 In addition, beside me is Dave Rudland
6 who is the current Branch Chief of that branch, so
7 hopefully between us we'll be able to answer any
8 questions you might have on our presentation. And
9 because I know we have a number of slides, I'm
10 going to turn it over now to Jeff and let him get
11 started.

12 MR. POEHLER: Thank you, M.J. First, I
13 just wanted to note the audience handouts, the
14 titles came out a little dark at the top of the
15 slide, so you might want to note on there what the
16 title is for later reference, just so you don't
17 confuse plants.

18 So I'm going to be talking about recent
19 operating experience with baffle-former bolt
20 degradation. What we're going to cover in this
21 presentation and we already did introduction.
22 First, we're going to cover design and function and
23 materials of PWR internals, the baffle-former
24 assembly and baffle-former bolts. We're going to
25 talk about some potential consequences of baffle-

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1 former bolt degradation. We're going to talk about
2 the history of baffle-former bolt degradation,
3 basically, the operating experience. We're going
4 to talk about some of the factors that influence
5 this type of degradation. We're going to talk
6 about how the bolts are inspected and replaced, how
7 baffle-former bolt degradation is evaluated, and
8 how the NRC is responding to the recent operating
9 experience. And then we're going to talk about the
10 NRC's future activities.

11 So here's a couple of figures. You're
12 going to see these again, probably. The one on the
13 left is just a general overview of PWR internals.
14 This is a Westinghouse-style PWR internals. The
15 blue structure is the baffle-former assembly and it
16 sits within the core-barrel assembly which is sort
17 of the large cylindrical structure that is the
18 largest component of the internals.

19 On the right is sort of a more detailed
20 view, what you would see looking at the inside of
21 the baffle-former assembly. You have a number of
22 plates and they are attached with bolts to these
23 horizontal plates which are called formers. And
24 you can see that on the cross section there, the
25 edge of the formers.

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1 Basically, the function of the baffle-
2 former assembly is to direct the coolant flow
3 through the core and also provide some lateral
4 support to the core during a seismic event or loss
5 of coolant accident. And basically, these plates
6 can form very closely to the outline of the core.

7 Here's a view looking down into an
8 actual Westinghouse PWR which you would see when
9 the reactor is defueled. You can see some of the
10 openings in this. At the top would be the core
11 barrel where you can see these two openings for the
12 inlet, either inlet or outlet flows.

13 So here on the left of this figure,
14 this is basically a plant view looking down of one-
15 eighth of the baffle-former assembly. And the
16 various different bolt locations are circled.
17 Here, these are the baffle-former bolts and then
18 you also have edge bolts which go in and connect
19 the corners of the plates and those sort of go in
20 here. And then on the outside -- this is the core
21 barrel and you have barrel-former bolts which
22 attach the formers to the core barrel.

23 On the right here, this is what you
24 would see if you were inside the core looking out
25 towards the baffle plates. This is what the

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1 baffle-former bolt heads look like. They're inset.
2 They're counter sunk into the plate and there is --
3 this is a locking bar which is welded to the baffle
4 plate on either side and that keeps the bolt from
5 backing out. And also, if the bolt were to
6 fracture, it would keep the bolt head from becoming
7 a loose part, presuming this locking bar was still
8 in place.

9 MEMBER SKILLMAN: Jeffrey, let me ask
10 this question, please. In this Figure 5, you show
11 the baffle-former bolts, those are from the inside
12 out.

13 MR. POEHLER: Right.

14 MEMBER SKILLMAN: You also show the
15 core barrel to former bolt. Those are from the
16 outside in.

17 MR. POEHLER: Correct.

18 MEMBER SKILLMAN: What is the failure
19 history of the latter, of the core barrel to former
20 bolt?

21 MR. POEHLER: Barrel-former bolts,
22 basically, there have not been any failures of
23 those. There might have been maybe one or two.

24 MEMBER SKILLMAN: But none or virtually
25 none.

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1 MR. POEHLER: Virtually none.

2 MEMBER SKILLMAN: So all the failures
3 are on the inside out?

4 MR. POEHLER: Right.

5 MEMBER SKILLMAN: Is there a
6 segregation of the shorter versus the longer shanks
7 for the failures?

8 MR. POEHLER: You mean among the
9 baffle-former bolts?

10 MEMBER SKILLMAN: Yes.

11 MR. POEHLER: Well, the shorter shanks
12 have generally higher stresses. That is a factor.
13 I'm going to talk about that a little bit later.

14 MEMBER SKILLMAN: I'd be curious if
15 there is a binning of the failures of the short
16 versus long.

17 MR. POEHLER: Yes, I'll talk about that
18 a little later, but yes, that is a factor and
19 different bolt materials tend to use a different
20 length shank, so that is also a factor.

21 MEMBER SKILLMAN: Thank you.

22 MR. RUDELL: If I may also, one thing I
23 wanted to point out on this particular photo
24 because I don't think we have it, is that some
25 baffle-former bolts have an internal hex design as

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1 this one does with a locking bar or locking tab
2 sometimes it's called, and welds associated with
3 that. Some of them have an external hex with a
4 locking bar and some of them have an internal hex
5 with a locking washer. So between the different
6 varieties of baffle-former bolts, there may be a
7 half a dozen different designs. And of course,
8 you've got to tailor, you need to tailor your
9 examination for that particular design.

10 And as you can note here, they weren't
11 made to get ultrasonic examination easily because
12 the original requirements were not to do in-service
13 inspection ultrasonic examination of these bolts,
14 but industry has worked hard to develop and fairly
15 recently demonstrated techniques to examine these
16 bolts. But it is challenging with regards to bolt
17 geography to do an ultrasonic examination with
18 bolts.

19 MR. POEHLER: And I just wanted to note
20 this is what -- this is like the type of bolt style
21 that's used in the Westinghouse four-loop plant.
22 And the bolts are about 5/8ths inch diameter shank
23 and about 2 inches long, so they're about the size
24 of your thumb. The heads are a little bigger.

25 So what are the materials used in

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1 baffle-former bolts? In Westinghouse plants, type
2 347 stainless steel is used in the older
3 Westinghouse plants. The bolt design for the 347
4 bolts has a sharper head-to-shank radius and
5 shorter shank as we mentioned than in the Type 316
6 cold worked bolts. Type 316 cold worked stainless
7 steel is used in newer generation Westinghouse
8 plants and all replacement bolts that are installed
9 to replace degraded bolts.

10 In other NSSS designs like Babcock &
11 Wilcox design PWRs use Type 304 baffle-former bolts
12 and combustion engineering plants use Type 316
13 annealed material. There are only two combustion
14 engineering plants that have bolts. Most of them
15 have a welded core shroud.

16 MEMBER KIRCHNER: Is this a good time
17 to ask just from a technical basis or metallurgical
18 basis, is there any reason why 347, have you seen
19 any technical reasons why 347 is failing versus
20 316, just based on materials?

21 MR. POEHLER: Just as far as
22 metallurgically-wise, I don't know that we have a
23 good explanation of why 347 is failing more. But
24 it is -- the operating experience clearly shows
25 that it's more susceptible.

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1 MR. RUDELL: Our international
2 experience early on was with 316 bolts in the EDF
3 plants and so I wouldn't necessarily conclude that
4 347 is significantly inferior material to 316
5 because we've seen quite a few 316 bolts fail,
6 mostly in international units in EDF.

7 MEMBER RICCARDELLA: Isn't there test
8 data and doesn't test data show difference in the
9 two?

10 MR. WILSON: I don't believe there is
11 very much test data that shows say a clear
12 difference between the two. And I think that's the
13 issues we run into. There's enough design
14 differences between the bolts, say we don't have a
15 real good one-to-one comparison across the board to
16 make a conclusion on relative susceptibility based
17 purely on material.

18 MEMBER RICCARDELLA: And then what
19 about the cold worked versus annealed on the 316?
20 Is there any evidence of one being better than the
21 other?

22 MR. WILSON: I am not aware of any
23 personally.

24 MEMBER RICCARDELLA: Cold worked would
25 presumed to be higher strength?

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1 MR. WILSON: Right, yes. Cold worked
2 is. Again, as far as OE is concerned because you
3 start out with different pre-loads, with one design
4 versus another, it's again, you're fighting I'd say
5 some design differences to make -- and it's making
6 it difficult to make any material judgment between
7 the two.

8 MEMBER RICCARDELLA: Between the three
9 really.

10 MR. WILSON: What's that? Between the
11 three, right, exactly right.

12 MEMBER RICCARDELLA: Thank you.

13 MR. POEHLER: The geometry of the type
14 347 bolts is with a shorter shank and sharper
15 radius creates higher stresses. So it may be a
16 function where the geometry that was used with the
17 347 bolts, but it's basically operating experience
18 is showing they're more susceptible.

19 CHAIRMAN SUNSERI: Jeff, you said that
20 the older Westinghouse plants had the 347 and the
21 newer had the 316. Do we know what prompted that
22 change? It must have come before the experience
23 with the degradation?

24 MR. POEHLER: Yes. I'm not sure. I
25 would have to defer to Westinghouse to answer that.

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1 MR. WILSON: This is Bryan Wilson from
2 Westinghouse. I can't answer directly why the
3 change was made at the time. There was a change in
4 the manufacturing processes that were intended to
5 be used. I don't know -- the difference in the
6 material follows that change in the manufacturing
7 process very well. So it may have been an
8 efficiency gain at the time, you know, given no
9 other evidence of material differences.

10 CHAIRMAN SUNSERI: Okay. Thank you.

11 MEMBER RICCARDELLA: Is the cracking
12 pretty much exclusively in the fillet radius or
13 have we had any evidence of cracking in the thread
14 regions?

15 MR. WILSON: There has been for some
16 plants, yes, there's been indications either at the
17 head-to-shank transition or the first thread.

18 MEMBER RICCARDELLA: Thank you.

19 MR. RUDELL: Bernie Rudell. It's
20 overwhelmingly been at the head to shank, that's
21 correct.

22 MEMBER RICCARDELLA: Thank you.

23 MR. POEHLER: So now I'm going to talk
24 about some of the potential consequences of baffle-
25 former bolt degradation. One of those is potential

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1 movement or deflection of baffle plates. If you
2 have large numbers of degraded bolts, that can
3 allow detachment or deflection of the baffle bolts
4 mainly during a LOCA or seismic event. And if that
5 happens, the plates could impact on peripheral fuel
6 assemblies and potentially cause fuel grid crush
7 and localized fuel cladding damage.

8 Some plants also have control rods in
9 peripheral locations which if the plate impact and
10 the fuel assembly damage was severe enough, it
11 could jeopardize capability to insert those
12 peripheral rods. One mitigating factor is you have
13 baffle-edge bolts which if they're intact they
14 would help retain those plates and keep even with a
15 lot of broken baffle-former bolts, it would help
16 retain the plates from the moving. And we haven't
17 seen any -- very little degradation of baffle-edge
18 bolts I'll say.

19 Also, if you do get localized damage to
20 peripheral fuel assemblies, you can perform a
21 coolable geometry evaluation to show that core
22 coolability would still be maintained.

23 Another consequence is baffle jetting
24 which is basically flow leakage through the gaps
25 between adjacent plates. You have baffle edge

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1 bolts which basically help hold the corners of
2 those plates together and that helps to prevent
3 baffle jetting.

4 You can get -- but if you do get baffle
5 jetting, basically the flow leakage out between the
6 corners causes flow and just vibration of fuel pins
7 resulting in localized -- which can result in
8 localized fuel cladding damage. In some cases
9 reaching the cladding. This can be detected by
10 reactor coolant activity monitoring which can
11 detect increases in flow and activity that can be
12 indicative of fuel damage.

13 MEMBER KIRCHNER: Jeff, did I
14 understand you correctly to say that you have seen
15 little baffle edge bolt damage versus the other
16 bolts?

17 MR. POEHLER: Yes. They have seen very
18 little, but I will be touching on that later that
19 one plant has found a few degraded edge bolts.

20 MEMBER KIRCHNER: Again, I'm searching
21 for is there a technical reason why the edge bolts
22 wouldn't fail at the same probability or
23 statistically at the same rate as the other baffle
24 bolts?

25 MR. POEHLER: I can't really speak to

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1 that. There may be differences in stress.

2 MR. WILSON: I can help you out there,
3 Jeff. There are differences in stress on those
4 edge bolts. The edge bolts are generally not very
5 highly loaded when all the baffle-former bolts are
6 in plate. As you start getting degradation,
7 significant degradation, you start to shift that
8 load and create additional loads on those edge
9 bolts.

10 MR. RUDELL: There is also less gamma
11 heating on the edge bolts, right?

12 MR. POEHLER: They are influenced less
13 by the gamma heating. I wouldn't say there's less
14 gamma heat --

15 MEMBER SKILLMAN: But less dose?

16 MR. POEHLER: No, I wouldn't say that.
17 Same dose. Another consequence is loose parts.
18 Bolt heads and locking bars can become loose parts
19 as the bolts completely fracture.

20 The clearances between the baffle
21 plates and fuel assemblies are very small, probably
22 in the order of that, which would tend to prevent -
23 - the bolt heads really can't escape unless the
24 reactor is de-fueled, but they can cause spreading
25 of fuel assemblies because they're bearing right on

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1 the fuel assemblies and they're caught in there.

2 MEMBER SKILLMAN: Jeffrey, has there
3 been any experience where a peripheral fuel
4 assembly has been blocked from removal because of
5 the --

6 MR. POEHLER: There's parts wedged in
7 there?

8 MEMBER SKILLMAN: No, because of the
9 head of the bolt backing out and the fuel assembly
10 not being able to slide freely out of that cell.

11 MR. POEHLER: Not that I'm aware of.

12 MR. WILSON: No, we have not had them
13 experience that.

14 MR. POEHLER: But because these bolt
15 heads are relatively small, if you had a few failed
16 bolt heads, it's unlikely that the -- we don't
17 think the loose part monitors would pick that up.
18 If you had maybe a large number of loose heads, you
19 might.

20 Baffle plates are unlikely to detatch
21 during normal operation, but if they did, the
22 potential for travel of the plate is limited by the
23 type clearances and the large size of the plates.

24 Okay, now I'm going to go into the
25 history of the operating experience or baffle bolt

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1 degradation. So the early history, it was first
2 identified in the late '80s in European plants, in
3 the French 900 megawatts CPO plants, that should be
4 a capital M, not a small M in front of the W.

5 Six plants found between about 1
6 percent and 11 percent of the bolts degraded and
7 the French plants -- the Belgian plants --

8 MEMBER SKILLMAN: Wait a minute. Not
9 so fast, not so fast. I understand that those CPO
10 plants all are downflow plants.

11 MR. POEHLER: They were originally
12 downflow, but they did convert to upflow in the
13 early '90s.

14 MEMBER SKILLMAN: Hold on. The
15 experience that you are pointing to is experienced
16 during the time those were downflow plants. Is
17 that accurate?

18 MR. POEHLER: Some of the inspections
19 were during the '90s after they converted.

20 MEMBER SKILLMAN: I don't feel like I'm
21 getting a good answer to my question. My
22 understanding is only the CPO plants had a
23 significant number of baffle-bolt failures.

24 MR. POEHLER: Right.

25 MEMBER SKILLMAN: The upflow plants did

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1 not, the CPY plants.

2 MR. POEHLER: That's correct.

3 MS. MALIKOWSKI: That's correct. This
4 is Heather Malikowski. We have a slide on the EDF
5 experience with a little more detail.

6 MEMBER SKILLMAN: So as you go through
7 the rest of these slides, I'd like to know what is
8 upflow and what is downflow.

9 MR. POEHLER: We will be covering that,
10 yes.

11 MEMBER SKILLMAN: Thank you.

12 MR. POEHLER: So in the Belgian plant
13 the one three-loop Framatome 900-megawatt design is
14 basically very similar to the CPO design.
15 Performed five examinations between '91 and 2014.
16 They found a total of 74 bolts degraded or
17 uninterpretable.

18 Three other plants performed one
19 ultrasonic examination each, finding just a handful
20 of degraded bolts. So the mechanism for this
21 degradation was attributed to irradiation-assisted
22 stress corrosion cracking, or IASCC.

23 In 1998, the NRC issued Information
24 Notice 98-11 to alert U.S. plant licensees to this
25 issue. And then the U.S. industry kicked off a

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1 program which included pilot inspections of baffle-
2 former bolts at several plants.

3 So I am going to talk about the pilot
4 plant inspections that were done in the U.S. There
5 were two two-loop downflow plants. These were
6 Westinghouse designed plants, the Type 347 bolts.
7 And those were ultrasonically examined in the late
8 '90s. Those plants found in the neighborhood of
9 seven to ten percent of the bolts in each site, in
10 each unit were degraded. So it came out to around
11 maybe 50 some bolts per reactor. They replaced
12 degraded bolts. One plant replaced a number of
13 additional non-degraded bolts for additional
14 margin.

15 One of the plants, they performed
16 tensile testing of bolts that were removed that had
17 indications and those tensile tests were good which
18 indicated that it seemed like some of the UT
19 results were false positives or over calling the
20 indications.

21 And also two three-loop downflow plants
22 or reactors with Type 316 bolts did an inspection,
23 same time frame. They found no indications, but
24 they preemptively replaced about 200 bolts per each
25 unit.

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1 And also, one B&W plant in 2005 found no
2 indications.

3 MEMBER SKILLMAN: You identified that
4 the two-loop 1990 Westinghouse plants are downflow.
5 The three-loop are downflow.

6 MR. POEHLER: Yes.

7 MEMBER SKILLMAN: Are all B&W plants
8 upflow? Is that accurate?

9 MS. MALIKOWSKI: Yes, that is correct.

10 MEMBER SKILLMAN: Thank you.

11 MR. POEHLER: Now we are going to talk
12 about MRP-227-A. Around the year 2000 to 2011, we
13 had a bunch of plants applying for license renewal,
14 PWR plants now we're talking about. And at the
15 time, there was the industry reactor vessel
16 internals Aging Management Program was not
17 developed yet, was under development, so a lot of
18 those plants made commitments to implement the
19 industry program when it was issued. That program
20 was MRP-227 rev. 0 was received by the NRC in 2009.
21 We were reviewing it in the 2009 to 2011 time
22 period. And we issued a safety evaluation on it in
23 2011. The approved or NRC-endorsed version of that
24 topical report is MRP-227-A which is the inspection
25 evaluation guidelines for PWR internals published

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1 by EPRI.

2 So I'm going to talk about what MRP-
3 227-A requires as far as inspection for baffle-
4 former bolts. Basically, ultrasonic examination
5 for the initial baseline examination. Westinghouse
6 and CE have the same schedule and scope. It's 100
7 percent of the bolts and it's to be done between 25
8 and 35 effective full-power years. For B&W, it's
9 slightly different. It's still 100 percent of the
10 bolts, but the timing is no later than two
11 refueling outages from the beginning of the license
12 renewal period.

13 And then for both -- for all the
14 different vendor-type of reactors, the follow-up
15 inspections are going to be ten years, a maximum of
16 ten years after the initial inspection. That's if
17 you don't find -- now if you found significant
18 degradation you might have to do it sooner, do the
19 follow-up inspections sooner. And all PWRs have to
20 do these inspections unless they don't have bolts.

21 So now in 2010, D.C. Cook Unit 2 found
22 visual signs of failure in several -- a number of
23 bolts. D.C. Cook is a four-loop Westinghouse
24 downflow plant. Has Type 347 bolts. There are 832
25 total bolts and they saw 18 bolts that had visual

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1 indications of failure. They ended up replacing a
2 total of 52 bolts with Type 316 bolts. Most of
3 those were on one large baffle plate. And a total
4 of the 52 they replaced, 42 were cracked. That
5 also includes the original 18 that they saw
6 visually in that 42.

7 To establish extent of condition, they
8 were basically from the three similar large baffle
9 plates. Basically, there's four of the baffle
10 plates are big plates and have a lot of bolts. On
11 all of the similar plates, the licensee performed a
12 VT-3 visual examination. Didn't see any visual
13 evidence of degradation and they tensile tested one
14 bolt from each plate and that came out fine. So
15 they concluded there was no degradation. They
16 didn't perform ultrasonic testing on any bolts.
17 And they left two bolt locations vacant when they
18 started up.

19 Westinghouse issued a technical
20 bulletin about this operating experience to alert
21 licensees.

22 MEMBER RICCARDELLA: Why were two bolts
23 left vacant? And was there a reason for that?

24 MR. WILSON: This is Bryan Wilson from
25 Westinghouse. Yes, upon completion of the

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1 replacement campaign, there was initially no
2 intention to replace the bolts near the edge
3 because we felt that they were supported
4 appropriately by the replaced bolts.

5 During the campaign and after it was
6 completed, we found there were say bolts that had
7 pushed the lock bars out as a result of basically
8 torquing up all the replacement bolts. So there
9 was potentially some damage at those bolts that had
10 caused the lock bars to pop out. So at that time,
11 the tooling had already been removed from site and
12 evaluations were done to show it's okay if we can
13 remove them and leave them like that.

14 MEMBER RICCARDELLA: Okay, it wasn't
15 for research purposes?

16 MR. WILSON: No, no, no. It was purely
17 --

18 MEMBER RICCARDELLA: Okay.

19 MR. POEHLER: Now I am going to talk
20 about in the 2011 to 2015 time period there were a
21 number of plants performed their initial
22 inspections as required by MRP-227-A. These were
23 the Westinghouse two-loop, mostly Westinghouse two-
24 loop designs and three-loop designs, also a few B&W
25 designs. So the Westinghouse two-loop, as we

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1 mentioned, they are Type 347 bolts. They did their
2 inspections at around 30 to 40 EFPY. See, these
3 are some of the oldest Westinghouse units. They
4 found no more than about ten percent max of any of
5 the units, the ten percent maximum of the bolts
6 were degraded.

7 The Westinghouse three-loop plants were
8 not quite as old, 30 to 32 EFPY. They also used
9 Type 347 bolts. There were four reactors. Three
10 of the units to the 100 percent inspections and
11 found basically very few bolts, no more than eight
12 per reactor and one of the units did a partial
13 inspection, but didn't find any indications.
14 They'll complete that at a subsequent outage.

15 Also, there were three B&W reactors
16 that had the UT inspections and they found no more
17 than -- the largest number of bolts failed per
18 reactor or with indications I should say, was four.
19 So really just a handful. None of the combustion
20 engineering plants with bolts have performed their
21 inspections to date.

22 MR. RUDELL: There is only one CE plant
23 that has baffle-former bolts that's still
24 operating.

25 MR. POEHLER: Yes, one of them is

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1 shutting down or shut down.

2 MR. RUDELL: Shut down.

3 MR. POEHLER: But the other one has
4 plans to do it in a few years, but they will meet
5 the inspection time requirement.

6 MEMBER SKILLMAN: So Jeffrey, just for
7 consistency, in the first group, the Westinghouse
8 two-loops, those are downflow plants, correct?

9 MR. POEHLER: They are downflow --
10 originally downflow. Some of them may have
11 converted at least one may have converted.

12 MEMBER SKILLMAN: Is there data that
13 shows pre and post conversion for baffle-bolt
14 failure?

15 MR. POEHLER: No.

16 MEMBER SKILLMAN: Thank you.

17 MR. RUDELL: That main data would be
18 the EDF plants and we'll show you.

19 MR. POEHLER: Now I'm going to talk
20 about Indian Point Unit 2. The 2016 refueling
21 outage, they conducted the MRP 227-A inspection.
22 The edge bolts were all acceptable. UT and visual
23 examination found about 227 potentially degraded
24 bolts out of 832 total. Some of those were found
25 ultrasonically. Some were visually detected and

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1 others, there were 14 inaccessible bolts and
2 inaccessible bolts are considerably assumed to be
3 degraded or failed.

4 So what did they do for corrective
5 actions? They replaced 278 total bolts. That was
6 all 227 of the potentially degraded. They also
7 replaced 51 additional non-degraded bolts to
8 provide additional margin. And they used Type 316
9 stainless steel. They completed an analysis to
10 support return to service. That was inspected by
11 NRC Region I inspectors and they sent a number of
12 bolts to the laboratory for testing to support root
13 cause analysis.

14 For the other unit at Indian Point,
15 Indian Point 3, there was an operability evaluation
16 performed which considered information from Indian
17 Point 2 and Salem 1 which I'll talk about in a
18 minute.

19 MEMBER BALLINGER: I have a question.
20 We're getting a little bit loose with the
21 definition of 316. Are they L or standard grade?
22 They're cold work 316L grade?

23 MR. WILSON: No, cold work 316
24 standard.

25 MEMBER BALLINGER: Standard grade.

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1 Okay.

2 MEMBER RICCARDELLA: Excuse me, what
3 were the EFPYs for Indian Point 2 and 3?

4 MR. POEHLER: It was about 31 for Unit
5 2 and Indian Point 3 was about 27.

6 MS. MALIKOWSKI: It was just under 31
7 for Indian Point 2.

8 MEMBER RICCARDELLA: Okay, and 27 for
9 3.
10 Thank you.

11 MEMBER BALLINGER: Is there a reason
12 for not choosing L? Because you can get the same
13 strength for culvert no matter what. It's dual
14 certified, right?

15 MR. WILSON: Yes. I can't comment on
16 that, unfortunately.

17 MEMBER BALLINGER: Okay, and they're
18 all standard grade, all the replacement 316s are
19 standard grade?

20 MR. WILSON: That's correct. I'm
21 sorry, for the Westinghouse replacement, yes.
22 There are differences for other vendors.

23 MEMBER BALLINGER: But you're creating
24 a whole separate database?

25 MR. WILSON: Right.

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1 MR. POEHLER: At Indian Point 3, they
2 rescheduled --- their baffle-former bolt
3 examination had been scheduled for 2019. They
4 moved it up to 2017.

5 Now I'm at Salem Unit 1. Also had a
6 spring 2016 refueling outage. It's another four-
7 loop Westinghouse downflow plant, with Type 347.
8 They were conducting first visual examination,
9 basically based on the Indian Point operating
10 experience. Then they found about 11 bolts with
11 visual indications of failure. Or actually, no, it
12 was a total of about 30 bolts with visual
13 indications failure. Eleven cracked at the head.
14 Nine had lock bar. The lock bars were cracked and
15 19 of the bolts were protruding, bolt heads were
16 protruding. So they decided to UT all the
17 remaining bolts. They found 135 more bolts that
18 were degraded based on UT and there 16 bolts that
19 were unable to be UT'd. So those were also assumed
20 to be degraded. So overall, there was about 190
21 bolts identified as potentially degraded and
22 needing replacement.

23 There were significant clustering of
24 bolts in several octants of the baffle-former
25 assembly, so the bolts, the degraded bolts were

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1 heavily concentrated in those areas and more sparse
2 in the other areas.

3 MEMBER SKILLMAN: Jeffrey, what
4 consideration was given to the meaning of that
5 bullet? It seems to me that that's a very
6 significant finding from all of the data coming out
7 of Salem 1. So what is the conclusion of the
8 Westinghouse team for the clustering?

9 MR. POEHLER: Yes, I'm going to talk a
10 little about the clustering. It's definitely been
11 seen at these four-loop plants and it was more
12 severe at Salem. So I'm not sure we have an answer
13 for why it was more severe at Salem than at Indian
14 Point. I don't know if the Westinghouse team has
15 an answer for that.

16 MEMBER SKILLMAN: Well, let me ask --
17 are the reactor coolant pump flows and reactor
18 coolant pump discharge heads the same for the two
19 plants?

20 MR. WILSON: They are very similar, the
21 two plants. Not enough to conclude a major
22 difference.

23 MEMBER SKILLMAN: Are the loop
24 geometries and the pipe diameters the same?

25 MR. WILSON: I can't answer that here.

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1 I'd have to confirm that one. I don't know off the
2 top of my head.

3 MEMBER SKILLMAN: I'm obviously
4 picking. Is there a standing wave or is there a
5 resonance that comes from main passing frequency
6 times four pumps, full power at the density that
7 you're at full power?

8 MR. WILSON: Right.

9 MEMBER SKILLMAN: It just seems to me
10 that there is information there that the very
11 curious might try to mine.

12 MR. WILSON: Right. The one thing we
13 do know is from looking at this, the flow into the
14 baffle-former region has to go through a path that
15 is a little bit more torturous than the norm. So
16 it has to enter through a flow hole in the side of
17 the barrel and then down through the formers. It
18 doesn't -- usually what happens at that point is a
19 lot of these say pressure variations and things get
20 kind of washed out a bit by the time you make that
21 path change.

22 So there hasn't been a strong
23 correlation with say pump-induced related
24 influences, but such as I think the disturbances
25 you're mentioning. But that certainly is stuff

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1 that we'll continue to look at as understanding the
2 situation.

3 MEMBER RICCARDELLA: Does the fracture
4 morphology show any signs of fatigue and is it
5 conclusive, whether it be fatigue or stress
6 corrosion?

7 MR. RUDELL: I can -- yes, there is
8 fatigue in the bolts that we've looked at so far.
9 Some have a significant amount of fatigue, maybe 50
10 to 60 percent of the failed fracture surfaces
11 appear to be fatigued, and then others nearly all
12 is intergranular, appears to be irradiated as
13 stress corrosion cracking. And we're trying to put
14 those pieces together. That's why we don't have a
15 whole lot of information in the destructive
16 examination work that's ongoing right now.

17 MEMBER RICCARDELLA: But it should also
18 tell you if it's high cycle versus low cycle.

19 MR. RUDELL: Yes. We're trying to get
20 that out of it, but you're right. It could be high
21 cycle or low cycle fatigue, depending on what comes
22 first.

23 MEMBER RICCARDELLA: But the fracture
24 morphology should identify that, right?

25 MR. RUDELL: Yes.

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1 MEMBER RICCARDELLA: I mean that would
2 address your concerns about the vibration.

3 MEMBER SKILLMAN: What I'm really
4 thinking is that the CPY plants, the French plants
5 that are four-loop that are different than the CPOs
6 that are four-loop downflow, the CPY plants are
7 four-loop upflow. And this problem has basically
8 ceased for the CPY upflow. So my hunch is that
9 there's a standing wave and that there's a
10 resonance cavity back in the lower internals of the
11 Westinghouse design where the clustering would
12 occur.

13 It's probably something envisioned, but
14 it just strikes me that the downflow, upflow, and
15 geometry of your baffles in the Westinghouse large
16 plants invites a question that really gets to what
17 Dr. Riccardella is talking about. If it's high-
18 cycle fatigue and it's preponderance, then I would
19 suspect that there's a standing wave and what
20 you're really getting is tensile failure as a
21 common -- as the consequence of fatigue.

22 MR. WILSON: Right. So for the upflow
23 and downflow, there's a significant difference in
24 the -- I'd say steady pressure, you know, that's
25 behind that plate. So any kind of influences of

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1 these say stress fluctuation or pressure
2 fluctuations or anything would even be further
3 magnified by that say steady difference. I mean
4 it's basically an order of magnitude difference in
5 pressure, in Delta P across that plate which is
6 enormous.

7 MEMBER SKILLMAN: The real issue is the
8 area because those plates are large plates, so even
9 small Delta P magnifies to a very large force
10 around those bolts.

11 MR. WILSON: Right.

12 MEMBER RICCARDELLA: Because then you
13 would -- would you see -- that's obviously worse at
14 the top than at the bottom.

15 MR. WILSON: Right.

16 MEMBER RICCARDELLA: Are we seeing a
17 trend of more cracking near the top?

18 MR. WILSON: Yes. The patterns of
19 failed bolts tend to be clustered in areas of the -
20 - right, in the U.S., in areas of the highest
21 pressure. So there's a clear trend there.

22 I'll touch on this clustering topic a
23 little bit more in my presentation later. I know
24 Jeff has some additional thoughts on this.

25 MR. POEHLER: Okay, Salem, what did

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1 they do? Correct actions. They replaced 189
2 bolts, the Type 316. They also sent some bolts to
3 the lab for analysis. They did a minimum bolting
4 pattern analysis to determine or to confirm that
5 their replacement scope was acceptable for one-
6 cycle operation prior to reinspecting.

7 For the operating unit, Salem Unit 2,
8 they performed an operability determination based
9 on the extent of condition from Salem Unit 1. They
10 also moved up the schedule UT examination of the
11 bolts to next year from 2026.

12 MEMBER RICCARDELLA: Just to complete,
13 what were the EFPYs for Salem, just two
14 centimeters?

15 MR. POEHLER: It sounds a little less
16 more in the 24 to 26 range.

17 MS. MALIKOWSKI: Salem 2 is in that
18 range, and then Salem 1 is 28.

19 MEMBER RICCARDELLA: Salem 1 is 28 and
20 Salem 2 is --

21 MS. MALIKOWSKI: Twenty-five.

22 MEMBER RICCARDELLA: Twenty-five.

23 MS. MALIKOWSKI: It will be 25 -- I
24 believe in the spring.

25 MEMBER RICCARDELLA: Thank you.

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1 CHAIRMAN SUNSERI: I would like to
2 remind the speakers to make sure you speak loud
3 enough so the transcriber can hear you.

4 MS. MALIKOWSKI: My apologies.

5 MR. POEHLER: Now D.C. Cook Unit 2 was
6 performing UT inspection during the fall outage and
7 this is the first plant to do the UT in accordance
8 with some interim guidance from the MRP, EPRI MRP
9 which we'll talk a little bit more about later.

10 They found a total of 179 potentially
11 degraded bolts. There were also, as I mentioned,
12 the two vacant bolt locations from 2010.

13 Some notable new elements at D.C. Cook
14 where there were six of the replacement bolts
15 installed in 2010 had indications. At least --
16 also, at least one of the vacant bolt hole
17 locations correlated with some damage to a fuel
18 assembly.

19 MEMBER SKILLMAN: Jeffrey, would you
20 please explain that more?

21 MR. POEHLER: The damage to the fuel
22 assembly?

23 MEMBER SKILLMAN: Yes.

24 MR. POEHLER: I mean it was basically
25 damage to the fuel assembly that was suggested of

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1 baffle jetting type issues going on.

2 MEMBER SKILLMAN: So jetting from an
3 empty hole?

4 MR. POEHLER: Apparently.

5 MEMBER BALLINGER: Now the replacement
6 bolts were 316 though, right?

7 MR. POEHLER: Correct.

8 MEMBER BALLINGER: So this is 316 bolts
9 that are cracked?

10 MR. POEHLER: Right.

11 MEMBER SKILLMAN: So wait a minute.
12 Damage fuel assembly jetting from an empty hole, so
13 what did the plant do? Did they remove this fuel
14 assembly and correlate basically a shine on a fuel
15 assembly or a set of pins or a spacer grid with a
16 location of the adjacent hole? Is that what that
17 means?

18 MR. WILSON: Yes, they had correlated
19 the location. Actually, one of the fuel rods had I
20 guess been displaced inward and they correlated the
21 location of that fuel rod with the spacing from --
22 or to that location of the hole.

23 MEMBER SKILLMAN: Of the hole.

24 MR. WILSON: Of the hole. Within like
25 an inch or so of that location.

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1 MEMBER SKILLMAN: Okay, thank you.

2 CHAIRMAN SUNSERI: So based on the
3 experience with baffle jet fuel failures, why was
4 that not anticipated? It seems like that that
5 should have been anticipated as a potential
6 consequence.

7 MR. WILSON: Right, at the time -- with
8 the lack of UT available at the time of that
9 inspection for that configuration of bolt, we did,
10 I guess, as much of what we thought was an extent
11 of condition at the time as we could, removing
12 bolts in those locations, and then, I guess,
13 expected that we had covered the range of failures
14 of those bolts at the time.

15 And the conclusion was that if we had
16 locked down the plate by putting these replacement
17 bolts in, that the baffle plate would have been in
18 contact with the former plate such that you
19 wouldn't really have a path for flow to get out of
20 that hole.

21 So the baffle jetting occurs when you
22 have some flexibility that allows a joint to open,
23 but we had expected that that joint would have been
24 closed or mostly closed, at least to the point
25 where you could accept the amount of bypass in

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1 jetting that was occurring, could occur from that
2 hole. What we come to find out later is that say
3 to the left of that, those replacements could have
4 potentially been an additional amount of failed
5 bolts that were undiscovered by the path that was
6 chosen for looking for an extent of condition. And
7 if those bolts were already failed, there was a
8 mechanism to kind of loosen that whole section of
9 the plate and allow for flexibility that allowed
10 flow to go through.

11 MR. RUDELL: To Bryan's point, those
12 two holes were vacated in 2010, coming out of that
13 outage. So there were prior cycles where there was
14 not any damage to the fuel associated with those
15 holes and there were other units that are operating
16 with baffle-former bolts vacated and I know the one
17 I'm familiar with does prescribed inspections. I
18 suspect that this unit did, too, particularly
19 looking at the fuel assembly in that area, and
20 knowing that that has a vacated baffle-former bolt
21 there.

22 And the inspections I'm familiar with
23 have not seen any indications of any jetting
24 associated with those vacant holes. So here we
25 have in this past cycle, this past operating cycle

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1 at this one plant discovered this issue with the
2 jetting out of vacated hole.

3 MEMBER SKILLMAN: Did the primary
4 chemistry, cesium and strontium, elevate,
5 indicating a weaker --

6 MR. RUDELL: They indications of a
7 failure. Yes.

8 MEMBER SKILLMAN: They did. Thank you.
9 Thanks.

10 CHAIRMAN SUNSERI: Were these vacant
11 holes near the top of the former plate or lower?

12 MR. POEHLER: I think the next slide.
13 This is a diagram -- this is the diagram of the
14 baffle former assembly at D.C. Cook showing the
15 locations. This is showing the as-found condition
16 in the 2016 outage. And the way this works is the
17 green bolts were good bolts with no indications.
18 Red bolts have indications. And I think the gray
19 ones were the empty holes which are somewhere right
20 about in that area. One of them is right here and
21 the other one is over here.

22 So this is the large baffle plate,
23 right here. This is where in 2010 they had
24 replaced the 52 bolts or most of them. So you can
25 see these sort of -- the ones with the square

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1 symbol are the replacement bolts.

2 In this yellow box here, this is the
3 six replacement bolts that were found degraded and
4 this right here is where they found five degraded
5 edge bolts as well, right here, on this seam here.

6 MR. RUDELL: So the sea of red.

7 MR. POEHLER: Yes, you note that
8 there's quite a few degraded bolts around where the
9 edge bolts were and these five edge bolts were all
10 in a row right on this.

11 MEMBER KIRCHNER: How does the -- with
12 your map here, just refresh my memory. How do the
13 primary coolant loops line up with the orientation
14 there? And in particular, where's the cold leg
15 coming in? Is that immediately adjacent to the red
16 field of degraded bolts?

17 CHAIRMAN SUNSERI: Before you answer
18 that question, let me make a request here. I've
19 got some feedback from the people listening on the
20 public lines. Since this is kind of a -- NRC is
21 leading this presentation, but we have other people
22 speaking, please identify yourself so that the
23 people on the line can understand who is talking.
24 Thank you.

25 MR. WILSON: So this is Bryan Wilson of

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1 Westinghouse. Yes, the cold leg is in that
2 vicinity. It's not exactly adjacent to those
3 failures, but --

4 MEMBER KIRCHNER: This is where you
5 would see the maximum pressure differentials,
6 especially with the downflow?

7 MR. WILSON: Not necessarily. Because
8 of the way the flow kind of has to go around the
9 annulus and then into the flow holes, it doesn't
10 necessarily line up always with the cold leg.

11 MEMBER KIRCHNER: But this is a
12 downflow design?

13 MR. WILSON: Yes.

14 MEMBER KIRCHNER: I would expect this
15 to be the point of highest pressure.

16 MR. WILSON: That is the elevation of
17 highest pressure.

18 MEMBER KIRCHNER: Then going back to
19 Dick's earlier comments on vibration --

20 MEMBER SKILLMAN: Let me push a little
21 further on Dr. Kirchner's question. Is there
22 history of operating with less than four pumps on
23 this plant? In other words, could they have run
24 for any extended time with two pumps on that loop
25 where that is the cold leg dominant location?

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1 MR. WILSON: No, I don't think there's
2 any experience with operating for an extended
3 period of time with that, with less than four
4 pumps.

5 MEMBER SKILLMAN: I don't know the tech
6 specs for this plant, but I know that you are
7 permitted for a certain time period less than four,
8 but it's a short time period. But I'm just
9 wondering if this is on a loop closest to where
10 there might have been an extended time period of
11 less than four-loop operation for the standing wave
12 on this corner of the internals might have been
13 greatest from the pumps that were operating in the
14 loop closest to that baffle.

15 MR. WILSON: Right, we have actually
16 looked at -- we were primarily looking at pump
17 sequence, end of start up and things like that.
18 Related to your question, we were not able to come
19 to a definitive conclusion that you would have
20 expected a correlation between this. It certainly
21 looks like there's a correlation, but from a fluid
22 hydraulics standpoint, it doesn't, you know, the
23 math doesn't work out, I guess, if you will.

24 MEMBER SKILLMAN: It could be
25 manufacturing, too.

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1 MR. WILSON: Right.

2 MEMBER SKILLMAN: So I understand that.
3 But I just wanted to build on Walt's question.
4 Thank you.

5 MEMBER RICCARDELLA: Just to complete
6 the story, the EFPYs for Cook 2 and also I don't
7 see much about Cook 1.

8 MS. MALIKOWSKI: This is Heather
9 Malikowski. This is 28 EFPY for Cook 2.

10 MEMBER RICCARDELLA: Twenty-eight in
11 2016?

12 MS. MALIKOWSKI: Correct.

13 MR. POEHLER: Okay, so the corrective
14 actions for Cook 2 was -- they're still underway,
15 but they plan to replace a minimum of 181 bolts
16 with Type 316. And that includes all the degraded
17 bolts, plus the missing vacant locations. And
18 they're planning to replace additional bolts up to
19 201 bolts as time permits in their outage.

20 They're investigating the indications
21 in their replacement bolts. I just want to note
22 that there have been replacement bolts in service
23 for about 10 to 15 years from some of the late '90s
24 inspection activities and they have seen no
25 indications in those replacement bolts, Type 316

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1 bolts.

2 The replacement bolts are going to be
3 sent for laboratory analysis. I think that's being
4 done very soon.

5 They're also having a sensitivity
6 analysis performed to explore the effects on
7 replacement bolt stresses from some of the failed
8 original bolts in that area that would support the
9 root cause for the replacement bolt failures.

10 So as far as the baffle edge bolts, the
11 licensee is still determining what they're going to
12 do about corrective actions for those. It's
13 possible they may not remove them.

14 Now I'm going to go into factors that
15 influence baffle-former bolt degradation. The
16 first one is neutron fluence. So austenitic
17 stainless steel is normally very resistant to
18 stress corrosion cracking in a PWR chemistry
19 environment. However, when you get high fluence,
20 you get grain boundary and chemistry changes
21 occurring.

22 The neutron fluence threshold for IASCC
23 is 2 times 10 to the 20 per neutron per square
24 centimeter or 3 dpa. Baffle plates and bolts, some
25 baffle plates -- areas of the baffle plates and

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1 bolts are going to get up to 75 dpa over a 60-year
2 life. However, the patterns of the bolt
3 degradation we've seen it at Indian Point 2, Salem
4 1, and Cook 2, don't seem to correlate with the
5 highest fluence locations in the core.

6 Also, I'd like to note that the two and
7 three-loop Westinghouse plants had similar higher
8 fluence levels to the four-loop plants, but fewer
9 degraded bolts.

10 CHAIRMAN SUNSERI: We need to be a
11 little careful about fluence threshold at 2 or 3
12 dpa. That also requires an environment. So the
13 microstructure is susceptible after 2 or 3 dpa, but
14 you still have to have the environment which is not
15 a PWR environment, right? In a BWR 2 and 3 dpa,
16 you're off to the races for this material.

17 MR. POEHLER: Yes, I mean it can
18 happen, the PWR environment. But at a low dpa like
19 3 dpa, you're going to need a very high stress.
20 It's kind of a sliding scale of stress versus dpa,
21 so the higher the dpa, you can have it at lower
22 stress levels.

23 MEMBER RICCARDELLA: Could you also
24 expect there to be a threshold at the other end,
25 too, at the high end where you damage -- the damage

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1 somewhat saturates and beyond that, additional dpa
2 don't matter?

3 MR. POEHLER: Yes, I mean the
4 mechanical properties at some point are going to
5 saturate as it further increases in tensile and
6 yield strength. Grain boundary chemistry might as
7 well.

8 MEMBER RICCARDELLA: What's that dpa
9 level?

10 MR. POEHLER: I don't know if I have a
11 precise answer.

12 MEMBER RICCARDELLA: It doesn't have to
13 be precise.

14 MR. POEHLER: I'm thinking something
15 around 15 maybe.

16 MEMBER RICCARDELLA: Okay. Thank you.

17 MR. POEHLER: Also, one other thing,
18 you know, most of the plants have switched to a low
19 leakage core design so that's going to reduce the
20 flux to the bolts which could slow initiation of
21 new IASCC cracks. Some of these may have initiated
22 earlier in life.

23 Let's talk about stress. So baffle-
24 former bolts have stresses from a variety of
25 sources. You have bolt pre-load early in life.

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1 That will relax due to radiation assistance stress
2 relaxation in a fairly short time of operation.

3 At higher fluences, you get void
4 swelling in the baffle plates and that can put
5 different stresses on the bolts such as bending
6 stresses as the plates grow vertically.

7 You also have differential pressure so
8 in a downflow plant design it's greater than in an
9 upflow design. And that's going to become more of
10 a factor as your pre-loads relax.

11 You also have differing numbers of
12 bolts per plate area. And a four-loop plant has a
13 larger core, larger plate area, but it has --- a
14 four-loop basically has the same or less bolts than
15 a three-loop plant.

16 Also bolt geometry, the head-to-shank
17 radius, different geometries were used for
18 different bolt styles, especially the 347, as we
19 mentioned, has the sharper head-to-shank radius
20 than the 316 design.

21 Fatigue loads can also have an
22 influence that's affected by the number of
23 transients you've had over the life of the plant.

24 MEMBER RICCARDELLA: Jeffrey, there
25 you're referring to low cycle fatigue as opposed to

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1 vibration fatigue that Dick is alluding to.

2 MR. POEHLER: Right.

3 MEMBER SKILLMAN: One thing that you
4 didn't show and you may have considered, you just
5 didn't write it down, is manufacturing tones. When
6 you look at the map of the bolts, one can
7 conceivably think that while the internals were
8 being constructed, was constructed over a series of
9 days as the bolts were inserted, torqued, and
10 strapped, it may have had different crews,
11 different materials, bolts from different lots.

12 So my question is what consideration
13 did you give to manufacturing issues?

14 MR. POEHLER: Obviously, if the pre-
15 load varies, if you had a higher pre-load or pre-
16 load was out of spec or at the high end that --
17 that could potentially be a factor early in life as
18 far as stresses. But if pre-load is low, then it's
19 going to relax faster, too. If you're on the low
20 end, maybe you get fatigue occurring sooner because
21 your pre-load relaxes. So that's -- those are
22 factors that in the root cause for these plants
23 they're going to need to look at if they have that
24 history in the manufacturing.

25 MEMBER RICCARDELLA: Are these

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1 lubricated when they're torqued?

2 MR. POEHLER: Yes, they generally are,
3 yes.

4 MEMBER BALLINGER: These are machined
5 bolts, not forged and then machined? Are they
6 machined from bar or are they hot headed and then
7 machined afterwards?

8 MR. WILSON: Yes.

9 MEMBER BALLINGER: Yes and yes and yes?

10 MR. WILSON: So this is Bryan Wilson
11 from Westinghouse. It depends on which bolts
12 you're referring to because there are differences
13 between the 316 and the 347 and how they were
14 manufactured. All of them were thread rolled.

15 MEMBER BALLINGER: So the threads are
16 rolled threads?

17 MR. WILSON: Yes. But the heading was
18 either done by machining like in a 316 or by hot
19 heading for the 347.

20 MEMBER BALLINGER: Hot heading.

21 MR. WILSON: So that was -- when I said
22 earlier about manufacturing differences between a
23 347 and 316, there was a transition where they went
24 from hot heading to machining these bolts. And so
25 yes, the 347 to start with the nominal shank of the

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1 bar and then hot head to -- you know.

2 MEMBER BALLINGER: That explains the
3 347 actually.

4 MR. WILSON: Yes.

5 MEMBER BALLINGER: Okay. I get it.

6 MEMBER SKILLMAN: Will the review of
7 the manufacturing records be conducted?

8 MS. MALIKOWSKI: This is Heather
9 Malikowski, Exelon. Yes, they have reviewed what
10 they can retrieve. And I believe Bryan can
11 elaborate. I believe there's only a few heats of
12 material that were supplied for the bolts, but we
13 can't correlate them to where they were put in the
14 plates. So we know there's only a few common
15 heats, but there's nothing to help say we can say
16 oh, it's just this heated material. Those records
17 were looked for.

18 And I think as far as the manufacturing
19 and assembly, I mean they found what they can, but
20 there's not enough granularity to it to say you can
21 say there's some sort of rework or something like
22 that that may have also helped lead to a focusing
23 of the failures.

24 MR. WILSON: Right, yes, there wasn't a
25 smoking gun, if you will, you know, related to

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1 manufacturing defects.

2 And as Heather pointed out, these were
3 supplied in batches and installed as such. There
4 was control of the parts to a plant as far as what
5 heats and stuff went to a plant, but not specific
6 location on an individual plate.

7 MEMBER SKILLMAN: Let the record show
8 that some of these plants were manufactured and
9 constructed before there was an Appendix B to 10
10 CFR 50. Now that doesn't mean that these
11 individuals who assembled these plants were
12 careless. They used the greatest caution and the
13 best material and the best assembly practice that
14 they knew. There might still be some lessons
15 learned from digging in some of those old records
16 is all I'm saying.

17 MR. WILSON: Understood.

18 MEMBER SKILLMAN: Thank you.

19 MR. POEHLER: Okay, now moving on, I'm
20 going to explain the difference between downflow
21 and upflow. So this diagram shows on the left,
22 this is a downflow plant. And basically here's --
23 the difference is flow direction in the space
24 between the core barrel here and the baffle plates.
25 Here are your former plates. You have holes in the

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1 former plates.

2 In a downflow, you have a hole up at
3 the top of the core barrel, the OD of the core
4 barrel where a flow comes in and flows down, a
5 portion of the flow flows down to this space and
6 then up out at the bottom and up through to join
7 the rest of the core flow through the core.

8 In an upflow plant, these two flows are
9 parallel. There's no hole up here, so between the
10 baffle and the core barrel space, flow is also
11 going the same direction. So the DP, differential
12 pressure, is very little with these two. Pressures
13 are very similar, whereas in the downflow, there's
14 quite a bit of difference, especially in the top of
15 the baffle-former assembly.

16 So this kind of shows if you did an
17 upflow conversion, you would plug that hole there,
18 but even with an original upflow plant, you just
19 would never have a hole up there.

20 MEMBER SKILLMAN: What is involved in
21 an upflow conversion? How many holes need to be
22 plugged?

23 MR. WILSON: This is Bryan Wilson,
24 Westinghouse. All of the core barrel holes are
25 plugged.

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1 MEMBER SKILLMAN: How many?

2 MR. WILSON: I'm not an upflow guy.

3 MEMBER SKILLMAN: In a fuel assembly
4 plant, there are 168 holes in the bottom. I would
5 imagine it's a number like that on the core barrel
6 periphery.

7 MR. WILSON: No, it's on the order of
8 like say 16 to 32.

9 MR. RUDELL: A couple dozen. It's
10 going to vary between two, three, and four-loop and
11 also the design for the holes that are now going to
12 be added and upper former plate will vary. And the
13 Delta Ps also vary after you do that design,
14 depending on the design of the flow holes through
15 the other plates that were there originally. And
16 they vary. And the degree of reduction in Delta P
17 that you get will vary depending on the design of
18 the original plant and the flow holes in those
19 baffle formers. So it gets complicated.

20 The work itself is all done, of course,
21 under water and controlled, special tooling,
22 special controls for foreign material and other
23 things. And as well as all of the design analysis.
24 Now your accident analysis need to be revisited.
25 Many of them need to be revised with all of the new

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1 core bypass values, even going back to your core
2 physics specifications will be changed accordingly,
3 so from an engineering standpoint, there's a lot of
4 paperwork and design modifications, 50.59 reviews,
5 and revisions to perhaps a lot of these accident
6 analyses. So it's quite an undertaking to convert,
7 but it is and can be done.

8 MEMBER RICCARDELLA: Is there a
9 significant difference in power output in the fluid
10 or not?

11 MR. RUDELL: I guess I wouldn't say
12 significant with the higher core bypass flow. You
13 will lose some of --

14 MEMBER RICCARDELLA: I mean a percent?

15 MR. RUDELL: About that.

16 MEMBER RICCARDELLA: Thank you.

17 MR. RUDELL: About that core bypass
18 flow, I don't know what it comes out to in power.

19 MEMBER SKILLMAN: Thank you.

20 MR. POEHLER: Now I'm going to talk a
21 little about the clustering effects. So the theory
22 that clustering is -- you initially baffle-former
23 bolts get random failures in random locations. You
24 get a failure of one bolt, that leads to load being
25 transferred to adjacent bolts and over several

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1 operating cycles this can cause the adjacent bolts
2 to the original bolt to crack which leads to
3 clusters of failed bolts. Some people call that
4 unzipping. That has been observed in French
5 plants when they did successive examinations. And
6 in the U.S., in the four-loop plants, the more
7 severe clustering was seen at Salem Unit 1.

8 So to summarize, some of the factors --
9 sorry.

10 MEMBER KIRCHNER: Jeffrey, may I
11 interrupt?

12 MR. POEHLER: Sure.

13 MEMBER KIRCHNER: Have you looked at
14 the patterns of clustering from plant to plant? Do
15 they correlate and do they correlate, I'm thinking
16 with the -- let's see, you have D.C. Cook, this
17 diagram here. Do the other plants show the same
18 clustering for degradation?

19 MR. POEHLER: You know, for Indian
20 Point, the clustering was less pronounced than
21 that. D.C. Cook, if you look at -- if you consider
22 where the 2010 failures were and that was pretty
23 clustered in that one plate. But Salem was
24 probably even a little more clustered than D.C.
25 Cook.

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1 MEMBER KIRCHNER: By clustering though,
2 could you give us a little more precision where was
3 it happening in the relative core location? At the
4 top, one would expect it, right?

5 MR. POEHLER: Yes.

6 MEMBER KIRCHNER: And in the smaller
7 plates?

8 MR. POEHLER: Yes, both smaller -- I
9 mean yes, smaller and larger plates, but at Salem
10 it was more over about three of the octants --
11 basically three eighths of the total baffle-former
12 assembly had a lot of clustering. And it wasn't
13 necessarily -- I don't know, maybe Westinghouse
14 could comment. I don't -- I didn't think it was
15 really more either at the top or bottom or center
16 of the elevation of the plates.

17 I think in Cook, as we definitely saw
18 that one cluster from 2010 was more toward the top
19 of the plate.

20 MR. WILSON: Yes, this is Bryan Wilson
21 from Westinghouse. I mean for Indian Point and
22 Cook, there seemed to be more of a trend towards
23 the top. I think the Salem was a little bit more
24 widespread at the time whenever the indications
25 were discovered. Whether it started in a certain

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1 location or not, is yet to be determined I think,
2 but it did have -- I'd say as the clustering tailed
3 off, it did have the trend to be say more towards
4 the top, not focused necessarily on the bottom.

5 MEMBER KIRCHNER: And to follow up, was
6 it more in the region of the smaller plates here,
7 this part of the core?

8 MR. WILSON: There was both. Well, as
9 far as -- coordinate location, you know, it was I'd
10 say clocked similarly to Cook where it was a large
11 patch in the wide plate, the 12 bolt wide plate and
12 that it moved. I'd say clustering was occurring to
13 say one side of that wide plate into the say
14 narrower plates.

15 MEMBER KIRCHNER: The narrower plates
16 having a higher Delta P across them?

17 MR. WILSON: No. They have the same
18 Delta P, but because of their width, the load per
19 bolt is slightly different.

20 MEMBER BALLINGER: The pre-load, back
21 to the pre-load, you say they were lubricated?

22 MR. WILSON: Yes.

23 MEMBER BALLINGER: And they're torqued.
24 Do you know what the uncertainty is on the pre-load
25 stress?

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1 I've got some experience with bolt
2 loads and sometimes that uncertainty can be
3 enormous, even for the best of circumstances.

4 MR. WILSON: Right, yes, I mean that
5 has all been studied many times in the variations,
6 but I don't know at that time what the variations
7 that they were measuring. I know a lot of testing
8 has been done since then to look at those
9 variations and account for them.

10 I can't comment specifically at that
11 point in manufacture, in this history what the --

12 MEMBER BALLINGER: Typically, 50
13 percent sometimes.

14 MR. WILSON: Right.

15 MEMBER RICCARDELLA: I've seen data
16 where if you're shooting for 70 percent, you're
17 getting anywhere between 50 percent and 90 percent
18 of yield.

19 MEMBER BALLINGER: And since IASCC is a
20 nonlinear function of stress.

21 MR. WILSON: Yes. Certainly, add to
22 the list of contributors, right?

23 MEMBER SKILLMAN: Let me ask to go back
24 to slide 25 just for a second, please? My question
25 is for Bernie.

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1 Bernie, you used the word 50.59. I
2 would think if a plant wanted to change from
3 downflow to
4 upflow, the 50.59 screening would very quickly push
5 you into a license amendment request. Is that your
6 understanding, too?

7 MR. RUDELL: I actually don't know
8 whether all these upflow conversions were done
9 under license amendment or not.

10 MEMBER SKILLMAN: Could you find that
11 out? It would seem to me that if you were to
12 decide in your going through the 50.59 which is
13 really a screening, you would tumble one or two or
14 several things, either a change in analysis, change
15 in fuel temperature, or major change in plant
16 design. And I would think number three would be
17 the hook that would require a license amendment
18 request. It's a curiosity question, but I concur
19 with you. This is a very substantial undertaking
20 and I'm not suggesting that anybody should do that
21 because of the magnitude of the work that is
22 involved. But I'm curious, there have been other
23 examples in industry where the applicant has used
24 50.59 and has suffered as a consequence by not
25 going to a full LAR, license amendment request. So

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1 would you get back to me, please?

2 MR. RUDELL: Okay.

3 MEMBER SKILLMAN: Thank you.

4 CHAIRMAN SUNSERI: Jeffrey, we are
5 slightly behind schedule here, so I'm not asking
6 you to speed up, but just be mindful of that. I
7 suspect with the discussion that we're making up
8 some time on the second part of this presentation,
9 but let's try to move the pace along a little bit.
10 Thank you.

11 MR. POEHLER: Yes, so just to summarize
12 some of the factors influencing degradation of
13 baffle-former bolts, it involves a complex
14 interaction of stress, fluence, and fault material
15 and design. You have some other aging mechanisms,
16 void swelling, and stress relaxation can both
17 influence IASCC bolts. Right now, the industry is
18 working on predictive models for baffle-former bolt
19 degradation which would account for all of these
20 different variables.

21 Also, the staff observation is that the
22 highest susceptibility to degradation seems more
23 related to stress differences rather than
24 differences in fluence between the various plant
25 designs.

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1 I'm going to briefly talk about
2 inspection replacement. I think we've talked a lot
3 about it already. Inspection is either by
4 ultrasonic or visual examination. Ultrasonic
5 testing is right now only for detection of flaws.
6 It's not demonstrated for sizing. Any bolt with a
7 crack-like indication is called potentially
8 defective.

9 Visual examination, VT-3, is not
10 specified for baffle-former bolts. Some plants
11 have performed voluntary VT-3s in response to
12 operating experience. It is used for the baffle
13 edge bolts as the primary inspection. VT-3 can
14 find evidence of failed bolts such as displaced
15 lock bars for treating or missing bolt heads. And
16 some of the failed bolts have been detected by
17 other visual inspections that were not VT-3
18 inspections such as those at Cook in 2010.

19 Replacement bolts, I think she's going
20 to talk a little more about this, but a lot of
21 bolts can be removed intact when you cut the lock
22 bar. The shanks, they're broken off. They can
23 sometimes be removed mechanically, but might
24 require electro-discharging machining.

25 The replacement bolt design uses an

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1 expandable locking cup, so you don't have to weld
2 on the highly irradiated baffle plate material.
3 And those bolts are 316 as we mentioned. They may
4 have been improved geometry or reduced stresses at
5 head-to-shank transition.

6 Next. Okay, so the next part of this
7 presentation I'm going to talk a little bit about
8 evaluation of baffle-former bolt degradation, how
9 do we evaluate when they find conditions that are -
10 - that don't meet the acceptance criteria.

11 I'm going to talk about acceptable bolt
12 pattern analyses. So there's WCAP-15029. That's
13 the NRC approved generic methodology for
14 determining acceptable patterns of intact baffle-
15 former bolts and that goes back to around 2000 when
16 they were doing the original pilot inspections.

17 The methodology uses the MULTIFLEX
18 computer code to determine accident loadings. Some
19 of the acceptance criteria include bolt stresses,
20 fuel grid impact loads, momentum flux which is a
21 parameter related to baffle jetting, also fatigue,
22 but high and low cycle fatigue and core bypass
23 flow.

24 When they evaluate, NES found bolt
25 degradation, any degraded is assumed to carry no

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1 load, no it's completely discounted in the
2 acceptable bolt pattern analysis. It does use the
3 irradiated material properties for bolts which
4 increases the strength of the bolts. And plants
5 have used this methodology both to evaluate as-
6 found conditions, you know, if you have a few bolts
7 degraded or it's okay to start up without placing,
8 and also for potential replacement patterns to make
9 sure that the stresses and other criteria are okay.

10 In some cases, you might not meet the
11 stress and fuel grid impact criteria and if you do
12 exceed those fuel grid impact criteria, you might
13 need to demonstrate a coolable geometry with some
14 damage to peripheral fuel assemblies. The WCAP-
15 15029 provides some guidance on how you do that.

16 CHAIRMAN SUNSERI: I'm not sure where
17 to ask this question. This might be a good place
18 to do it, but I noticed a lot of the evaluation of
19 acceptability has been based around stress and
20 structural concerns.

21 I had a question that I got from
22 looking at the Westinghouse Nuclear Safety Advisory
23 Letter. It deals with the emergency flow cooling
24 flow. I don't have a good sense for how much flow
25 can get past this baffle and maybe bypass part of

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1 the core. It indicated it was nominal. It was
2 dismissed as nominal, but I mean do we have more
3 quantification of that and whether that could
4 potentially be a problem in a severe unzipping if
5 you will?

6 MR. WILSON: Yes, so we did look at --
7 for the safety evaluation that was done by
8 Westinghouse. I'll talk a little bit about this
9 later, but we considered a condition where the
10 baffle plate was basically had no baffle-former
11 bolts intact. So I would say that's a very severe
12 condition. We also -- regarding edge bolts, we
13 assumed that the edges of the bolt -- of the baffle
14 plate were simply supported, such that the baffle
15 plate could flex inward towards the fuel assembly.

16 In that condition, it was evaluated at
17 about 4.5 percent or 1.4 percent bypass flow could
18 occur. That was looked at in these emergency core
19 cooling scenarios, LOCA and non-LOCA, and was
20 determined to be say within the bounds of margin,
21 it was available in those evaluations and the
22 levels of conservatism that were already built into
23 those evaluations.

24 So we don't expect, under that
25 circumstance, to be a concern with the amount of --

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1 CHAIRMAN SUNSERI: So it's within the
2 bounds of the margin, but I mean --

3 MR. WILSON: Yes, easily within. It
4 wasn't up against the edge. It was -- I'd say
5 dismissed as negligible with respect to what's
6 available in conservatism and margin.

7 CHAIRMAN SUNSERI: Okay, thank you.

8 MR. POEHLER: And I'll talk about
9 reinspection intervals. So if you do find a large
10 number of degraded bolts, there is another WCAP
11 17096 which staff recently approved. It's reactor
12 internals acceptance criteria and methodology and
13 data requirements. And this provides guidance for
14 engineering evaluation of baffle-former bolt
15 degradation. It actually covers all of the
16 different PWR internals, but baffle-former bolts is
17 one of them.

18 So there's a numerical margin which can
19 be determined which consists of additional bolts
20 over and above the number and the minimum bolting
21 pattern. The minimum bolting pattern is that
22 pattern that has the fewest number of bolts that
23 would meet all the acceptance criteria and that
24 also -- the location of the bolts is also a factor.
25 Obviously, if they're severely clustered they may

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1 not need certain stress criteria.

2 So what the WCAP 17096 says the number
3 of degraded bolts you find is less than half the
4 margin, you can continue -- you can start up and
5 reinspect again in ten years without replacing
6 those bolts. If the number of degraded bolts is
7 greater than half the margin, you have to justify a
8 different reinspection interval. So the plants
9 with these outages in 2016 that had large numbers
10 of degraded bolts, they would not have met the WCAP
11 criteria. So those plants elected to replace
12 essentially all, at least all the bolts that were
13 degraded through historical structural margin.
14 Industry is still developing models for failure
15 rates of baffle-former bolts. So we do need to see
16 reinspections of bolts at shorter intervals, at
17 least now, to establish what are the failure rates
18 of these bolts.

19 Okay, now I'm going to talk a little
20 about the NRC response to this operating experience
21 of baffle-former bolts. First thing is regional
22 inspections. So the NRC staff performed targeted
23 inspections at the three plants, Indian Point,
24 Salem, and we're currently still in the inspection
25 at D.C. Cook. Those inspections are focusing on

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1 the quality and accuracy of the non-destructive
2 evaluation. They're focused on the corrective
3 actions including how you show the operating unit
4 is still okay to continue operating. They focused
5 on adequacy of their replacement bolt pattern
6 including margin for additional failures during the
7 next cycle.

8 There's also these inspections, at
9 least for Indian Point or Salem are documented and
10 publicly available inspection reports. And
11 regional inspectors are engaging with other plants
12 with regard to operability evaluations and plants
13 with upcoming outages. And those are the plants
14 that -- mainly the plants that are similar to the
15 ones that have found the degradation.

16 MEMBER SKILLMAN: Jeffrey, how is the
17 inspection protocol established for these
18 inspections?

19 MR. POEHLER: How is the protocol
20 established?

21 MEMBER SKILLMAN: Yes. Do you have an
22 inspection procedure?

23 MR. POEHLER: They do.

24 MEMBER SKILLMAN: And how was that
25 established?

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1 MR. POEHLER: You mean specifically for
2 baffle-former bolts?

3 MEMBER SKILLMAN: Yes. At the top of
4 33, you're saying staff performed targeted
5 inspections. What's their basis for the
6 inspection? What does the inspection prove?

7 MS. ROSS-LEE: I'm sorry, wasn't the
8 initial inspection -- sorry, this is M.J. Ross-Lee.

9 I think at least the inspections were
10 done as part of the MRP 227A. So the aging
11 management said hey, you should look at these in
12 the certain EFPY for the plant. And so Indian
13 Point did that so -- that's what the inspections
14 were a part of was part of our aging management
15 program. So in this period of time you should
16 look, do this inspection, and that's what they were
17 doing at Indian Point.

18 MEMBER SKILLMAN: So if I repeat back,
19 it was part of the AMP for that plant?

20 MS. ROSS-LEE: Is that a correct
21 characterization of the MRP 227?

22 MR. POEHLER: Yes, what the licensee --
23 the physical inspections conducted by the licensee,
24 yes, are part of the AMP. But then the activities
25 of the NRC, I think you're asking about the

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1 activities of our NRC inspectors?

2 MEMBER SKILLMAN: I am. I'm referring
3 back to the first bullet on Slide 33.

4 MR. POEHLER: Basically, I don't think
5 they have a specific inspection procedure just for
6 baffle-former bolts. But the type of inspections
7 they were doing were -- they called it a problem
8 identification resolution sample, so it's, you
9 know, targeted at this specific issue, but --

10 MS. ROSS-LEE: We might have -- I'm
11 sorry, this is M.J. Ross-Lee.

12 There might be regional people
13 listening. We might have to get back to you. Yes,
14 so I answered the question on why the industry was
15 doing them. It was upon discover of the number of
16 degraded bolts which was greater than what was
17 expected that led our inspectors to engage and what
18 we're, I guess, referring to there as a targeted
19 inspection. But if you need more specific detail,
20 I'll probably have to try to reach out to one of
21 the regions to get those detailed answers.

22 MEMBER SKILLMAN: What I was really
23 exploring was the formality of this inspection,
24 whether it's a standing inspection procedure, or if
25 this is a special inspection protocol that has been

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1 developed between the NRC and industry, based on
2 the MRP, for these specific findings or whether
3 this is just a Keystone Cop showing up with a
4 magnifying glass and a sounding pin.

5 I have a hunch, it's very formal. It's
6 very well constructed. When you say it can be
7 reviewed, that suggests to me a level of inspection
8 formality that's very, very serious. So my
9 question is what is that? Is that an IEP? Is that
10 a special inspection? Is it just a PI&R? How
11 formal is this for the NRC inspectors because if
12 they have to do this at plants other than Salem and
13 D.C. Cook and Indian Point, perhaps there needs to
14 be a rigid formality to this.

15 MR. POEHLER: I mean I don't think it's
16 not a special inspection. It is a PI&R. But they
17 would have a test or an inspection plan ahead of
18 time.

19 MS. ROSS-LEE: We might -- I'm sorry,
20 this is M.J. Ross-Lee again. To get the answer to
21 your question, we have to get -- it's a formal
22 inspection. It's documented. There are inspection
23 reports that are issued on it. I don't have access
24 to those right here, but at least for the two that
25 are done and public, we can pull those up, find the

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1 actual inspection procedure that was used. So we
2 can get that information back for you. I just
3 don't have it with me right here.

4 MEMBER SKILLMAN: Thank you.

5 MR. POEHLER: Another part of the NRC
6 response was we performed what we call a LIC-504
7 evaluation. LIC-504 is an office instruction. The
8 title of it is Risk-Informed Evaluation of Emerging
9 Issues. It's basically a process we use to
10 evaluate the safety significance of new issues and
11 so we look at different options for addressing the
12 issue. Basically, it boils down to do you need to
13 -- is this a safety issue that warrants shutting
14 the plant down immediately or not?

15 But under the four options we looked at
16 for the baffle-former bolt issue were immediate
17 shutdown and inspection, or inspection next
18 refueling outage. This is inspection of the
19 baffle-former bolts. Doing a generic communication
20 to gather more information, or just maintaining the
21 status quo which would just be let them keep on
22 inspecting as per the guidance to the MRP 227 on
23 that schedule.

24 When you do the LIC-504 process, you
25 look at five criteria and compliance with existing

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1 regulations, consistency with defense-in-depth
2 philosophy, maintenance of adequate safety margins,
3 demonstration of acceptable levels of risk, and
4 implementation of defined performance measurement
5 strategies.

6 So what were the results of this LIC-
7 504 evaluation? Well, the risk met the two LIC-504
8 criteria are core damage frequency of less than 1
9 times 10 to the minus 3rd and large early release
10 frequency less than 1 times 10 to the minus 4 per
11 year. So if you're above those risk levels, then
12 that would indicate you probably need to shut down
13 immediately. If you're below them, you don't.

14 The risk levels for LOCA, they're
15 driven by basically the low frequency of large and
16 medium LOCAs results in low core damage frequency
17 due to LOCA. Small break LOCAs are more frequent,
18 but we don't think they have the potential to
19 detach or deflect baffle plates such that it would
20 cause significant fuel damage.

21 Also, there was a separate seismic risk
22 assessment performed that used bounding seismic
23 hazard curves in U.S. based on recent updated
24 seismic hazard submittals. And the seismic
25 assessment also assumed a 75 percent reduction in

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1 load-carrying capacity for the baffle-former bolts
2 which is much greater than we've seen at any plant
3 where it's been limited to about 25 percent
4 degradation.

5 MEMBER POWERS: I don't contest your
6 conclusion here, but it's -- I'm not understanding
7 exactly how you arrive at a CDF and a LERF analysis
8 here. You seem to be dependent on fairly large
9 LOCAs
10 to get an incremental risk. And so I'm wondering
11 how you concluded that those LOCAs were worse than
12 ordinary LOCAs, LOCAs without this problem? How
13 did you do that?

14 MR. POEHLER: So we have C.J. Fong here
15 from the Division of Risk Assessment. I think he
16 wants to speak to this question.

17 MR. FONG: Sure. Thanks, Jeff.

18 Hi, Dr. Powers. This is C.J. Fong at
19 NRR Division of Risk Assessment. I've got Steve
20 Laur on the phone who performed the detail risk
21 analysis. If we really want to get into the nuts
22 and bolts, I'll ask that we patch him in, but I
23 think I can at least take a shot at the initial
24 question.

25 What Steve did was he made the very

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1 conservative assumption that any initiating event
2 with the capability of imposing additional load on
3 the baffle-former bolts could deflect them such
4 that core flow would be blocked.

5 Now Mr. Wilson at Westinghouse pointed
6 out, we think that's probably not the case, but
7 just as a first cut, we assigned a conditional core
8 damage probability of one to any event that could
9 deflect or significantly deform the baffle-former
10 plates.

11 And so it turned out that it was large
12 and medium LOCAs. And what Steve did was he looked
13 at both your kind of traditional LOCA cost by long-
14 term material degradation and also LOCA that was
15 induced by seismic event. And as Jeff pointed out,
16 we used the weight of seismic curves and
17 fragilities and also Steve used the LOCA
18 frequencies from NUREG-1829.

19 MEMBER POWERS: Thank you. That
20 certainly illuminates what you did. It's certainly
21 a conservative approach. I'm struggling mightily
22 to understand how much of a public health and
23 safety risk this particular issues covers it. And
24 that kind of very conservative analysis is useful,
25 I think, especially if we're going through your

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1 process. It's not unreasonable, but it's not
2 illuminating for me with a realistic risk to public
3 health and safety is here.

4 I hope somebody can explore that a
5 little for me.

6 MS. ROSS-LEE: This is M.J. Ross-Lee,
7 NRR. So I think that based on the somewhat
8 bounding, perhaps conservative analysis that was
9 done, as well as other criteria that we looked at,
10 for instance, when you look at the different
11 options, we balance things like transience or
12 burden if we were to make them shut down as well as
13 well, if we don't do anything.

14 And I believe that considering the
15 realistic risk to the public is what led us to pick
16 the option that we did which is to have them do
17 inspections at a more frequent interval or sooner,
18 so everybody is committed to doing inspections at
19 their next outage at the most susceptible plant.

20 So I think we've tempered what the
21 actual numbers ran versus the other knowledge that
22 we have to feel comfortable that the risk to the
23 public is such that it is acceptable to do Option 2
24 which is waiting for the next outage. At that
25 point in time, perhaps based on those results that

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1 are gleaned, we would maybe have to relook at our
2 LIC-504, our choice in options.

3 So to quantify the realistic risk if
4 that's what you're looking for as far as a number,
5 we haven't done that. I do believe that we have
6 put a number of factors together to believe is one,
7 we don't need to shut them down right now, but
8 Option 4, we're not going to ignore this and just
9 wait and see what happens. So we picked what we
10 thought was the realistic option and that is to
11 have them move up the most susceptible plants in
12 the initial tier to move up their inspections all
13 of which will be completed by I believe the end of
14 2017.

15 MEMBER POWERS: Well, I think I
16 understand what you've done for now. What I am
17 wondering is what do you do in the future? Is this
18 a problem that we can say okay, problem resolved,
19 licensees, your problem or is it a continuing risk
20 to the public health and safety? I'm not getting
21 an understanding of why it's a continuing risk to
22 the public health and safety.

23 MR. FONG: Dr. Powers, I think the way
24 I would respond to that is that we really have two
25 separate risk-informed processes. LIC-504 is for

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1 emerging conditions. Do we have an immediate
2 safety issue where we need to have plant shutdown
3 right away? We feel the analysis we performed,
4 while conservative, was certainly sufficient to
5 support that decision.

6 Down the road, if there's a different
7 question, for example, should a licensee be allowed
8 to just live with this for the life of the plant,
9 that would be maybe a Reg. Guide 1.174 decision
10 which has different acceptance guidelines and it's
11 a different process.

12 So I think we used the right tool for
13 this decision. I certainly understand what you're
14 saying down the road, if there's a different issue
15 or different question that we're trying to answer,
16 we can enter a different process, like a license
17 amendment using Reg. Guide 1.174.

18 MEMBER POWERS: Thank you. I
19 understand exactly what you've done. My question
20 is a little different.

21 MS. ROSS-LEE: Sorry, this is M.J.
22 Ross-Lee. So I believe at this point in answer to
23 your question have we reached a decision that we're
24 just going to let industry do what they want with
25 this, I would say the answer to that is no.

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1 Again, this tool gave us an answer for
2 now. It had a recommendation that they need to
3 move up the inspections. We're going to look at
4 those inspections as an agency. We'll look at what
5 the results of those are. We're staying very
6 plugged in with the root cause analysis. That will
7 be looked at. At each of those steps
8 along the way, we'll have to look at what our
9 agency response is. We'll have to look at is the
10 current aging management guidance in MRP-227A
11 acceptable or do we need to, in fact, change the
12 inspection frequency in there because every ten
13 years isn't the right answer. So I certainly don't
14 feel that at any point we would just make this an
15 industry issue or problem. We'll continue to stay
16 engaged and we'll look at the tools that we have to
17 stay engaged and perhaps make changes as necessary,
18 based on the results that we get.

19 We have a couple of data points now.
20 We're aware of those. We'll get more data points
21 as we get inspections coming forward over the next
22 year. If our position on the safety significance
23 of this would change, we would react at that time.

24 MEMBER POWERS: The problem is I really
25 don't understand the safety significance here. I

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1 don't think you've outlined it. You've done a very
2 conservative analysis and it's probably one I would
3 have done to satisfy your immediate need. But to
4 go forward and say what beyond this, I think I'd
5 need a little more definitive, a little more
6 realistic kinds of risk analysis to tell me how
7 much effort I'm going to expend on this particular
8 issue from a regulatory perspective.

9 MS. ROSS-LEE: Noted. I know that at
10 the next point which we would have information to
11 inform any sort of analysis would be following
12 perhaps some of the bolt testing, some of the
13 material information which currently we don't have.
14 And we would have additional information from
15 follow-on inspections that could --

16 MEMBER POWERS: I'm not sure that's
17 your most formidable problem in getting to a
18 realistic risk assessment. I think your most
19 formidable problem is defending the idea you've got
20 LOCA codes that can handle realistic deflections of
21 the baffle-former plate to say there's any
22 incremental risk associated with that. I think
23 that's the challenge you're going to face is that
24 you're burdened because of the limitations of your
25 existing analytical capabilities to making pretty

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1 Draconian conservative assumptions here. And I'm
2 suspect of those. I think you'd have to come in
3 and put a pretty stout defense on what you've done
4 in your accident analysis tools. I don't know how
5 you do that. I don't think you have the data to
6 sustain an argument that there's a substantial risk
7 to the public health and safety from this.

8 MR. FONG: Dr. Powers, I think I would,
9 in general, agree with that. Risk, of course, if
10 frequency times consequence. I think we've got a
11 handle on the frequency of the different initiating
12 events. We recognize there's some uncertainty
13 there.

14 As far as the consequence goes, we had
15 to make a very conservative assumption that hey, if
16 the LOCA happens the baffle plates somehow enter a
17 geometry where they're blocking flow completely and
18 the core goes to core damage. I don't think that's
19 really 100 percent chance of that happening, but
20 right now don't have the information to assign a
21 more realistic value.

22 As M.J. pointed out, we're gathering
23 data. There's destructive engineering going on of
24 bolts and things like that. We might, in the
25 future, have a better way to model the consequences

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1 as part of the risk equation, but right now --

2 MEMBER POWERS: I am not at all
3 criticizing what you've done here. I am saying
4 that you can research the bolts until the cows come
5 home. You're not going to answer the real question
6 on what's the risk to public health and safety from
7 this particular event. That's not where the real
8 technical issue is going to be. It is precisely
9 the approximation that you found yourself forced to
10 make to do this that's going to be the real
11 question.

12 MS. ROSS-LEE: We are way behind. If
13 you could try to move through. I think we've
14 probably touched on this about as much as what
15 information we can provide and then I think go on
16 to the last slide.

17 MR. POEHLER: Yes. So second to the
18 last slide. So just to summarize the NRC's
19 evaluation of the recent operating experience. Our
20 preliminary conclusion is that it's the
21 Westinghouse four-loop design downflow plants with
22 Type 347 bolts that are more susceptible to baffle-
23 former bolt degradation than other PWR designs.

24 There are seven plants in that group
25 which are listed here. Also, EPRI is going to talk

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1 about -- industry is going to talk about this a lot
2 more, but the EPRI and Materials Reliability
3 Program has issued interim guidance that calls for
4 UT inspection of all baffle-former bolts at the
5 next refueling outage for these plants, these seven
6 plants which they call Tier 1A.

7 The NRC is also monitoring inspections
8 and other actions at all these plants. We feel
9 that the immediate safety concern for these plants
10 is addressed by our LIC-504 evaluation.

11 Finally, future activities for NRC,
12 we're following the root cause investigation at
13 D.C. Cook 2, focusing on the cause of degradation
14 in the replacement bolts and also the baffle-edge
15 bolts. We're going to look at the LIC-504 to
16 determine if it needs to be revised based on the
17 new developments at D.C. Cook Unit 2.

18 We are going to continue to engage with
19 the industry, especially on the root cause for the
20 three plants. We're going to discuss with the
21 industry if they need to make changes to the
22 interim guidance.

23 We plan to develop an information
24 notice. We are going to document our staff
25 assessment of the MRP's interim guidance. And

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1 finally, we're going to determine if changes to the
2 overall MRP-227-A guidance for baffle-former bolt
3 inspections are needed.

4 So that concludes the NRC's
5 presentation. If there are any further questions?

6 MEMBER KIRCHNER: I have a question
7 getting at root cause. Do you have maps of each of
8 the plants and where these baffle-bolt failures
9 occurred like the nice presentation you gave us was
10 Cook?

11 MR. POEHLER: Yes, we do.

12 MEMBER KIRCHNER: Have you looked at
13 these patterns and do you see any repeats in terms
14 of where you're finding clusters of bolt failures?

15 MR. POEHLER: I mean I think not
16 necessarily exactly the same patterns are seen in
17 all the plants. I don't know that we've done a
18 detailed analysis of that.

19 MS. ROSS-LEE: This is M.J. Ross-Lee.
20 I would say at least at this point we haven't --
21 there's not an obvious correlation or similarity in
22 those bolting patterns that we've been able to
23 determine.

24 MEMBER KIRCHNER: Thank you.

25 CHAIRMAN SUNSERI: All right, at this

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1 time, thank you for the presentation. Appreciate
2 the information you provided.

3 At this time, we're going to take a 15-
4 minute break. We will resume with the industry
5 presentations at 20 'til based on that clock.

6 (Whereupon, the above-entitled matter
7 went off the record at 10:25 a.m. and resumed at
8 10:40 a.m.)

9 CHAIRMAN SUNSERI: All right, we're
10 going to reconvene the Metallurgy Subcommittee
11 briefing here. We'll begin with the industry
12 presentation and Bernie Rudell is going to
13 introduce the team and start us off.

14 Bernie?

15 MR. RUDELL: Yes. Thank you very much.
16 It's a pleasure to be here with the Advisory
17 Committee to share our experience so far with
18 regards to this issue in the pressurized water
19 reactor industry, specifically with the baffle-
20 former bolt issues.

21 We have Heather Malikowski here today.
22 She's the chairman of the PWR Owners Group Material
23 Subcommittee. And Bryan Wilson, a member of that
24 committee as well, but he represents Westinghouse
25 and also a lot of the analysis that Westinghouse

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1 has done for both the technical bulletin back in
2 2012 and now additional analysis that's been done.
3 And you'll hear about that in this presentation.

4 I also have on the line, I believe,
5 Steve Fifitch. Are you there, Steve? He's there
6 and if we need so, he can jump in. He's
7 representing AREVA, also a member of the PWR Owners
8 Group.

9 My name is Bernie Rudell. I'm the
10 chairman of the Integration Committee of the EPRI
11 Materials Reliability Program and we have the lead
12 as an issue program under NEI-0308, the Materials
13 Degradation Management Program for the PWR reactor
14 vessel internals.

15 So we have representatives from both
16 the Owners Group and MRP and some PWR suppliers
17 here to present information.

18 Jeff did such an excellent job and I
19 read through his draft slides the other day and I
20 said there wasn't much left for us to present. So
21 hopefully, we can go through our slides and just
22 hit maybe some of the highlights where we heard
23 some questions and elaborate on those and you can
24 jump in with additional questions if they come to
25 mind. And we can give you the information that we

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1 know there or get back to you at a later time, for
2 example, with the 50.59 evaluation question that we
3 had earlier.

4 As I mentioned, baffle-former bolt,
5 we'll call it BFB, examination is a subset of the
6 PWR reactor vessel internals Aging Management
7 Program and that's really under the NUREG-1801 GALL
8 or General Aging Lessons Learned Program and the
9 NEI-0308 Guidelines for Management of Material
10 Issues and Inspections and Evaluation. That
11 guidance is prescribed in, as Jeff pointed out, our
12 MRP 227 and it's got the -A now because it also
13 includes the NRC's safety evaluation which accepts
14 that guidance on PWR internals and inspections.

15 This spring at two PWRs, a large
16 percentage of baffle-former bolts failed
17 examination that had typically been experienced
18 before. Before we were seeing one to five, and
19 maybe an occasional near ten percent failure of
20 baffle-former bolts.

21 Fortunately, there's a lot of margin in
22 the number of baffle-former bolts in these designs
23 and that margin varies, dependent on the design and
24 it depends on that particular station's LOCA
25 analysis and so forth as well. And the leak before

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1 break that has been adopted for that unit because
2 it's typically the LOCA and seismic event that
3 governs the minimum bolt pattern analysis which, as
4 Jeff pointed out, is also performed by NRC safety
5 evaluation accepted methodologies.

6 Although there's margin in the number
7 of required bolts from what is there originally,
8 these findings did trigger a substantial safety
9 hazard look-see under 10 CFR 21. And it turned out
10 that these findings do not constitute a substantial
11 safety hazard status under 10 CFR 21. The large
12 percentage did not meet the acceptance criteria
13 though in our WCAP 17096 that Jeff also alluded to.
14 And in these cases, the distribution of failures
15 have caused further attention to the topic,
16 particularly this clustering effect that we see.

17 In response to this experience, MRP
18 invoked the protocol for potential generic material
19 issue and that protocol is prescribed under NEI 03-
20 08. Westinghouse has issued a Nuclear Safety
21 Advisory Letter, NSAL. And AREVA has issued a
22 Customer Service Notice. The PWR and Material
23 Reliability Program formed a joint baffle-former
24 bolt focus group and have issued NEI 03-08 interim
25 guidance that was approved by the PWR Materials

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1 Management Program which is our executive branch,
2 if you will, under the NEI 03-08 issue program for
3 PWRs.

4 We've got a lot of attention to this.
5 The entire EPRI year emergent funds for emergent
6 issues has been allocated to the baffle-former bolt
7 work that's going on. We've redirected efforts
8 from lower priority work that we were doing to the
9 baffle-former bolt. There's a lot of research
10 involved here going on and both where it fits under
11 our appropriate jurisdiction in the PWR owners
12 group area and the EPRI MRP area and then in some
13 cases to the specific licensee and work they're
14 having done to go through and address
15 programmatically what they need to do as well.

16 So the guidance, as I mentioned, is
17 approved. A lot of that guidance so far as matched
18 up almost one for one with the NSAL, but the
19 guidance carries the NEI 03-08 needed requirements
20 there so that we would be informed as would the NRC
21 if there was any deviation from that guidance. And
22 for example, all of these Tier 1A plants have
23 inspection scheduled now in their upcoming
24 refueling outage.

25 Communications were had. We've had

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1 several face-to-face meetings. In fact, we had a
2 meeting with the focus group Monday this week in
3 San Antonio and there were about 70 people that
4 attended that meeting. So we're very interested in
5 this subject and getting it behind us as an
6 industry. And I think we're doing all of this in
7 the spirit of the GALL and the fact that this is a
8 living program. We're going to learn. We're going
9 to look at what appears to be the material
10 degradation areas that may pop up and adjust from
11 the results that we see. And in this case, I
12 believe we see a few plants, we hope limited to a
13 particular subgroup because and that's what it
14 appears to be. We'll show you evidence of that,
15 that we can get through and then resume to an
16 inspection and monitoring and replacement program
17 that will not cause us to hit unacceptable
18 conditions of the results in the future.

19 MEMBER POWERS: Is the apparent
20 confinement to a subset of plants just an accident
21 of time? That is, if I go out another 20 years,
22 then I'll find a broadened subset?

23 MR. RUDELL: That's a good question.
24 And our research is looking into that question.
25 Right now, today, where we are in time it appears

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1 to be a particular subset. But the information
2 that we get from a lot of this evaluation that
3 we're doing and we have a lot of very smart people
4 working on it will tell us do we need to change our
5 inspection on the other plants going forward? In
6 fact, that's what we'll be looking for in the next
7 set, perhaps, of interim guidance that will come
8 out. But that's a very good question.

9 MEMBER RICCARDELLA: To be clear,
10 inspections are planned under MRP 227 for all the
11 plants?

12 MR. RUDELL: That's correct.

13 MEMBER RICCARDELLA: It's just the
14 timing of them and whether you accelerate them.

15 MR. RUDELL: That's correct.

16 MEMBER RICCARDELLA: Thank you.

17 MEMBER KIRCHNER: Bernie, to frame the
18 issue again, just you have only to date found this
19 problem in the PWRs with downflow in the baffle
20 region, is that a fair assessment?

21 MR. RUDELL: The Tier 1 Alpha plants
22 are the four-loop design Westinghouse plants that
23 have operated and continually -- and are continuing
24 to operate in a downflow condition.

25 MEMBER KIRCHNER: Right, so those other

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1 Westinghouse plants or other PWRS with upflow are
2 not experiencing this problem based on outages and
3 inspection?

4 MR. RUDELL: That's correct.

5 MEMBER KIRCHNER: Okay, so you describe
6 the --

7 MR. RUDELL: Based on the inspections
8 that have been performed.

9 MEMBER KIRCHNER: -- root cause as a
10 metallurgy and materials issue. Is it not a fluid
11 hydraulic design issue with the plants in Tier 1?
12 And if you were to change out those plants to
13 downflow in the baffle region, would you
14 essentially solve this problem?

15 I think replacing bolts is less
16 expensive than changing flow configuration for the
17 plant, but I'm just -- getting at the root cause
18 may not be materials because as Dana might have
19 suggested will you see this with further aging in
20 other plants or is it really a fluid hydraulic
21 phenomenon problem that's inducing this?

22 MR. RUDELL: Well, can we hold off on
23 answering that response because I think there's a
24 lot of things at play here and what's leading and
25 what's lagging may even vary from one plant, a

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1 model, to another plant model as well.

2 Let me check -- so just in summary, we
3 have MRP 227 is the leading guidance that we have
4 now. We know that baffle-former bolts is one of
5 the primary exams, the degradation mechanism under
6 that, and the bases that back the creation of that
7 guidance indicate that it irradiated assisted
8 stress corrosion cracking and fatigue. Both of
9 those degradation mechanisms are susceptible to
10 occurring in baffle-former bolts.

11 We have expansion criteria that we
12 believe some of these plants have triggered and
13 they'll need to enter into the expansion
14 examination. The examination for baffle-former
15 bolts is 100 percent of the accessible baffle-
16 former bolts. And there's a prescribed time line
17 that we're changing with some of the interim
18 guidance now.

19 The UT that we perform is generally
20 capable of detecting large cracks on the order of
21 30 percent of the volume. And as Jeff mentioned,
22 the acceptance criteria is the WCAP 17096-NP-A
23 approved and the minimum bolt pattern WCAP.

24 So without further ado, I'm going to
25 turn it over to Heather, and we'll go through our

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1 presentations.

2 MS. MALIKOWSKI: Thanks Bernie. Thank
3 you, Bernie. This is Heather Malikowski. I am the
4 chair of the PWR Owners Group Materials Committee.
5 You'll see a lot of parallels in our slides with
6 what Mr. Poehler presented, so I will try and just
7 highlight certain points on some of them, but
8 otherwise, unless there are specific questions,
9 there's something you want to go back to on those
10 particular figures, I'm going to move relatively
11 rapidly.

12 As we discussed, I think we're pretty
13 much grounded on the configuration of the assembly
14 and this is where the baffle-former bolts are
15 located. And as we've discussed, the material
16 differences are there, mostly more correlated also
17 to the design of the bolts amongst the different
18 NSSS designs and the number of loops per plant. We
19 said the shank lengths do vary depending on the
20 design. And Bryan Wilson will probably go through
21 some more details on that, how it affected our
22 analyses.

23 We discussed the difference, obviously,
24 downflow and upflow configuration is a big part of
25 this discussion and so we'll continue to, as I go

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1 through, I'll just point out we do try and document
2 where for the plant inspections that have happened,
3 which plants are downflow versus upflow. We don't
4 have all the timing, say for the ones that have
5 converted in all cases whether their exams were
6 prior to conversion or not. If there's interest in
7 that, we can follow up.

8 For your reference, I think this is a
9 good time line to show. On the top it just gives
10 the operating experience where we started from back
11 in 1989 with the French OE and coming through to
12 the present with our more recent findings at Indian
13 Point, Cook, and Salem.

14 Down at the bottom it shows some of the
15 guidance that's been issued by the industry
16 including the NRC. We actually did -- I just want
17 to basically show that when the response to the EDF
18 OE in the late '80s, we did respond and review the
19 issue, looking for commonalities to the fleet,
20 comparisons of many parameters. At the time,
21 Westinghouse Owners Group put together comparisons
22 of all the different two, three, and four-loop
23 designs at the Westinghouse plants, trying to
24 understand relative risks in all of that to help
25 inform future guidance and recommendations for the

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1 industry.

2 So as you'll see, we get up to the late
3 '90s, that's when the pilot inspections that Jeff
4 referenced earlier were performed by a voluntary
5 selection of similar plants to the EDF plants to
6 get some additional information on the impact to
7 the U.S. fleet.

8 And you'll see that it looks like
9 there's kind of a large gap there where nothing
10 happened, but that is really not the case and I'll
11 kind of explain that there was ongoing work during
12 that time until between when we did inspections in
13 the late '90s until the MRP 227 industry guidance
14 came out.

15 MR. RUDELL: You can see this is almost
16 one of the first issues that the MRP worked on.
17 MRP-03 back in 1990 addressed the baffle-former
18 bolt OE that the French saw. And that inspired the
19 Owners Group to do a lot of inspections in 1990-
20 2000 time frame that you'll see as well in our
21 slides a little later.

22 CHAIRMAN SUNSERI: So it is a little
23 curious that the French plants and the comparison
24 to the U.S. plants, the similarities must be more
25 than just the design. Were they the same fluence

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1 and age of materials? So why were the French
2 having the problem and U.S. plants weren't, I guess
3 is my question.

4 MS. MALIKOWSKI: So moving up to our
5 past operating experience, the slide here does have
6 some summary of the EDF experience from the '80s.
7 They are a three-loop essentially Westinghouse
8 design. They do have definite design differences.
9 I don't know if anyone wants to elaborate on them,
10 but they are even within the CPO design as was
11 mentioned earlier. There are differences amongst
12 those design plants. So the plot here that EDF
13 shows is their inspection history over the last
14 several years, they use operating hours as their
15 nomenclature on the bottom for time. So it's a
16 little different than EFPY for us. So I don't have
17 the exact EFPY numbers.

18 But it basically shows that these are
19 all CPO plants shown, but they definitely have a
20 very small trend of finding any baffle-bolt
21 failures on was it Bugey 4 and 5 versus the
22 Fessenheim or the other Bugey units. What it shows
23 is that even though they did convert to an upflow
24 configuration, they do have -- they do continue to
25 find bolt failures, but not significant numbers and

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1 not -- I don't believe and the interest in the OE
2 is not necessarily clustered per se, but they are
3 continuing to get failures and it is generally
4 focused towards the high fluence regimes, the areas
5 down lower in the baffle region. So they're
6 basically seeing a continuing trend of failures,
7 but they're not seeing an accelerated trend because
8 they are doing replacements as they go along and
9 continuing a replacement in the inspection
10 campaign. So now they basically are tracking their
11 inspection requirements with an anticipated five
12 bolts per year failure rate and really looking at
13 more as an irradiated effect versus now we have the
14 extreme, the stresses have been lowered.

15 As we kind of discussed earlier, they
16 do have this 316 material, but obviously that was a
17 difference, but I think we are saying that's not
18 necessarily a big indicator that that's going to
19 fail quicker, because obviously our domestic
20 experience doesn't show that.

21 And so other than that, I think --
22 other than we know there's operational differences
23 of load following versus our more base load
24 operation, but it's not clear the magnitude of
25 impact they have on their failures. That's

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1 something that's being thought of as maybe a
2 contributor to their seeing the accelerated
3 failure, but I don't think we have a quantification
4 of that.

5 MEMBER RICCARDELLA: Heather, when the
6 French replace, are they replacing with 347 or 316?

7 MS. MALIKOWSKI: 316. And they have
8 replaced some replacement bolts, but we did confirm
9 that was not for -- because of failure. It was
10 actually just to continue to maintain the minimum
11 pattern and to continue to keep the overall age of
12 the bolts at a low amount.

13 MEMBER RICCARDELLA: Thank you.

14 MR. RUDELL: These are 316 originally.

15 MEMBER RICCARDELLA: Oh.

16 MR. RUDELL: Yes, all the French are
17 316 original baffle-former bolts.

18 MEMBER RICCARDELLA: Thank you.

19 MEMBER SKILLMAN: Heather, are the
20 Bugey 4 and 5, the blue and the yellow, the only
21 plants that are the three-loop upflows on this
22 image?

23 MS. MALIKOWSKI: I believe they're all
24 converted to upflow. I do not know if 4 and 5 are
25 original upflow or not. Do you know, Bryan?

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1 MR. RUDELL: They are all converted and
2 there is not a significant difference between Bugey
3 4 and Bugey 2, as I understand it, other than
4 perhaps in the time of life that it got converted,
5 but as far as I understand and as with a couple of
6 presentations from EDF and their experience and the
7 best information they brought with us, they were
8 all converted basically in the same year time frame
9 or within a few years and they don't have a big
10 explanation as to why some of these are unaffected
11 by this issue and some are.

12 Their rate going forward and their
13 philosophy going forward has been approximately
14 five bolts per year, their failure rate. And their
15 inspections and replacement pattern have been to
16 get to a point where they can go to an extended
17 ten-year interval between inspection and
18 replacement campaigns.

19 But basically, they've been using a straight five
20 bolt per year for original bolts' failure rate,
21 comparing it to their minimum bolt design analysis
22 and the replacement bolts they also have a lower
23 failure rate that they work with. And are even
24 replacing replacement bolts in the future.

25 MEMBER RICCARDELLA: On the Bugey 2

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1 curve, where approximately on that curve was the
2 change from downflow to upflow?

3 MS. MALIKOWSKI: I knew you were going
4 to ask. I can't say. Unfortunately, I'd have to
5 follow up to find where they're at on the curve as
6 far as the conversion time frame. I don't have
7 that number.

8 MEMBER RICCARDELLA: Thank you.

9 MEMBER SKILLMAN: It seems like that's
10 a key question during this whole presentation
11 because it suggests that Bugey 4 and 5 are running
12 almost flat and after 220,000 hours, just a couple
13 of indications whereas the other plants continue.

14 MR. RUDELL: But they're going through
15 large replacement campaigns in this time line also.
16 So that's where you need to have that piece also.

17 MS. MALIKOWSKI: And it may be a factor
18 of when they get their replacements done. Did they
19 do it prior to large failures starting?

20 MEMBER BALLINGER: Again, these are all
21 316 bolts?

22 MR. RUDELL: Yes, correct. 316 and
23 Monday, they said they're 316 cold work.

24 MEMBER RICCARDELLA: But when you
25 replace, you start to clock over again.

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1 MR. RUDELL: Yes.

2 MS. MALIKOWSKI: And as far as our
3 domestic experience, does help give some
4 information as far as kind of helping correlate
5 that yes, as far as upflow and downflow. And I'll
6 explain that on another slide here.

7 Just to summarize, as we said, back in
8 the late '90s, early 2000, we did have a Joint
9 Owners Group Program to do voluntary inspections in
10 relation to the Bugey OE. And so the selective
11 plants, they were Ginna, Point Beach, Farley 1 and
12 2. And as you note, from the results we note here,
13 and these were done basically because we're trying
14 to look for plants that were similar -- have the
15 longest operating time, so they tend to be the two-
16 and three-loop plants. And we're looking at
17 similar plants to Bugey, so there being three-loop
18 that we focused on those plants. We do not have a
19 four-loop inspection, but those tend to be -- they
20 were the younger plants and a different design. So
21 at the time, these were the plants that we did
22 inspect.

23 There were some UT indications found,
24 but as we note here for Ginna we did actually do a
25 metallurgical examination of 14 bolts after

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1 removal. We did do a replacement at that station
2 and there were no cracking found. So there at
3 least is some -- I believe we have some over calls
4 on our examination results which at least is
5 conservative so we've kind of bounded our -- the
6 concern there. But at the same time shows that
7 we're not seeing, we weren't seeing huge amount of
8 cracking in our fleet.

9 And you'll also note here, we did have
10 proactive replacements also done at the Farley
11 units even though they did not have any UT
12 indications. Basically, because we saw very little
13 indications from these examinations, that's where
14 we were led to the conclusion of all right, this is
15 not a current licensing period of concern for our
16 fleet. We do need to develop an aging management
17 guidance for license renewal and that's really
18 where the industry transitioned to was all right,
19 we need to develop that kind of guidance. So
20 that's where from this point on, we did say all
21 right, we need to develop inspection guides, but we
22 weren't then recommending further plant inspections
23 other than their normal in-vessel exams during
24 refueling for ISI.

25 And then to show some of the more

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1 recent inspection results now that we do have MRP
2 227 as our inspection requirement which does, as
3 Jeff had mentioned require UT inspection of 100
4 percent in 25 through 35 EFPY for the Westinghouse
5 NSSS.

6 The two-loop plants' examination
7 results are on the left-hand column. The three-
8 loop plants are on the right. You can see that
9 most of them are downflow configuration. The Point
10 Beach units are upflow converted. So we do have
11 some second inspection results on the two-loop side
12 and we have new inspections on the three-loop side
13 to show there really are very low amounts of
14 inspection indications being found and we are
15 seeing at least some amount of correlation that at
16 least to this point we're not seeing a significant
17 degradation effect. You can also see we do have
18 reference here where most of them are 347 stainless
19 steel in these plants.

20 For the other NSSSs, B&W and also some
21 international results, we're obviously talking
22 about EDF, but there are other results from other
23 utilities shown there. Also, similarly, very low
24 on inspection findings, and we do have actually
25 several multiple -- the third inspection has been

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1 done, just completed in August at Ringhals Unit 3
2 and finding a very small number of indications.

3 And note, we kind of mentioned this
4 briefly earlier, the B&W NSSS, their design is an
5 original upflow configuration. There's also many
6 slots and flow holes in the baffle plate, so
7 there's a lot of reduction in differential pressure
8 there. And as noted, there really was only one
9 crack-like indication detected in the four units
10 there, the three Oconee units, and actually
11 Crystal River. It was mostly inaccessibility they
12 called it, just saying because we couldn't inspect
13 it, that was the only other degradation fact except
14 for one bolt. So giving some a little credence to
15 the upflow design having some benefit there. And
16 also, as we note, the CE bolted design is also
17 upflow as the original design as well. So that's
18 why we've kind of seen -- the focus has been more
19 to the Westinghouse NSSS.

20 So just the broader OE, what we've seen
21 up until this spring, we basically noted that the
22 international OE and our domestic OE has really
23 reinforced that the failures are expected to be
24 IASEC with a random distribution. We did not see
25 any clustering or ready focused failures in one

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1 location or the other. They were bounded by
2 historic safety assessments we did the mid- to late
3 '90s. So we had some confidence that we were
4 within the bounds of analyses already performed.
5 And we did actually have quite a bit of replacement
6 campaigns executed in the utilities and
7 internationally and domestically that has seemed to
8 have been helping maintain those plants in going
9 forward.

10 So at least the experience up to this
11 point was we were seeing no major trends other than
12 what we would expect as a standard degradation
13 mechanism that would proceed randomly in the
14 assembly.

15 MEMBER KIRCHNER: So from this slide
16 would one conclude that downflow is the root cause
17 for the larger failure rate in the plants that
18 you're going to discuss next?

19 MS. MALIKOWSKI: I would say it's part
20 of it, but we will discuss that.

21 MR. RUDELL: The oldest operating PWR
22 in the U.S. is a downflow plant, a two-loop plant.
23 And that was one of the plants that was inspected
24 in 1999. It got 100 percent inspection. Now there
25 was some inaccessible because of the lock and weld

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1 rollover. One hundred percent inspection with a UT
2 technique that was at that time the best we had.

3 We found about 60 bolts. It's a 700
4 and some odd bolt baffle-former design and they
5 found about 60 bolts with UT indications. They
6 went to a replacement campaign. They were able to
7 replace 56 of those. During the 56 bolts' removal
8 at that time, 5 broke and the others didn't. They
9 took two of the broken bolts and 14 of the unbroken
10 bolts that came out that had UT indications and
11 sent them off to a hot cell for extensive
12 destructive examination.

13 One of the broken bolt fracture
14 surfaces was too destroyed by the removal operation
15 to get any valuable information out. The other one
16 showed 100 percent virtually intergranular, like
17 irradiated assisted stress corrosion cracking
18 fractography features.

19 The other 14, they were UT'd in the
20 shop with the shear wave on the side of the bolt
21 and they thought they saw indications in those
22 bolts. The other 14 then were ultimately PT,
23 fluorescent PT examination and they saw no
24 indications in those bolts. Of the 14, 2 were cut
25 up to do some tensile specimens and the other 12

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1 were pulled to failure. No PT indications, pulled
2 to failure, and they showed full strength expected
3 for their irradiated strength and basically they
4 were -- I'll just use the word flawless. So we
5 from that found that the sample out of 14 bolts
6 that came out whole, that had indications, all 14
7 were flawless.

8 Another plant at the time did a lot of
9 pull tests and in the pull at that time when they
10 were pulling, removing bolts, and they all came out
11 showing full strength. So here we are with a
12 downflow unit. I'm just answering your question
13 that as the oldest plant in the United States and
14 the last inspection, by the way, where we didn't do
15 100 percent inspection, but we inspected about 125
16 bolts. We had one bolt with an indication out of
17 100. So that's less than one percent. So it
18 almost looks like we had -- although this slide
19 said 7 percent or something like that, maybe really
20 was 1 percent back in 1999 in that unit and in
21 2011, when we looked at it under the MRP 227
22 program, it looked like 1 percent failure at that
23 downflow plant. So it's not downflow necessarily,
24 I think.

25 MEMBER POWERS: Aside from the focus of

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1 your presentation, does it appear that our
2 inspection technique is susceptible to a high level
3 of false positives?

4 MR. RUDELL: Well, we're learning more.
5 Of the bolts, we have about 30 bolts. I'm just
6 going to talk round numbers. We have about 30
7 bolts in the hot cell now out of Indian Point 2 and
8 half a dozen or so out of Salem and we took six
9 more of the bolts out of -- that were in the Ginna
10 spent fuel pool that were removed in 2011 and
11 they're in the hot cell also now.

12 We've only done of the bolts that were
13 removed intact from Salem and Indian Point, we've
14 only looked at four so far and it looks like those
15 four are flawless. So that's four of the red bolts
16 that appeared to note.

17 Now, on the other hand, I can't say
18 that without saying this. There were some green
19 bolts that were removed at one unit and they broke
20 so we got some of those also in the lab and we'll
21 look at those.

22 We know that UT is difficult. We know
23 that -- you need to certainly assume a ten percent.
24 Probably in most of our assumptions, we're assuming
25 a 20 percent probability of a detection being

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1 missed or a false call. So there is -- some of the
2 effort needs to go into understanding what's the
3 characteristic of these failures that are making
4 NDE not as accurate as we would like it to be as
5 well. And that's another element of our focus
6 group.

7 MEMBER RICCARDELLA: Was there a
8 significant improvement in the inspections from --
9 you know, the Ginna was like 1999, 2000 versus what
10 we're doing now 15 years later?

11 MR. RUDELL: I'd have to say yes. We
12 have now MRP-228 which governs some of the
13 inspection demonstration and qualification. The UT
14 on bolts, I understand, it's not an Appendix 8 PDI
15 qualification, but it's a low rigor qualification
16 one might say demonstrated. And we actually have
17 made a change going forward to increase the rigor
18 slightly of that.

19 MEMBER RICCARDELLA: But your initial
20 hot cell data at the Indian Point post is not --

21 MR. RUDELL: But I'm sure we're going
22 to find some of them failed, but I'm just saying
23 we're only four so far.

24 MEMBER RICCARDELLA: Yes.

25 MS. MALIKOWSKI: And I think you saw

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1 the figure, the picture that Jeff had in his
2 earlier presentation. This particular
3 configuration bolt was very difficult to get an
4 examination, a quality examination done. It's not
5 -- it's probably one of the most challenge of all
6 of the configurations we have. So unfortunately,
7 they do what they can to improve on the technique,
8 but it does still come down to being it's a
9 challenge to get a sound bounced back and forth and
10 read reliably so. I think calling it a little
11 conservatively has been the preference at least to
12 make sure that we're not missing things.

13 MEMBER RICCARDELLA: I understand.

14 Thank you.

15 CHAIRMAN SUNSERI: Based on the amount
16 of time that we have left today, I'm going to ask
17 you to prioritize your remarks now and make sure
18 you tell us the most important things that you want
19 us to hear. Okay?

20 MS. MALIKOWSKI: I understand.

21 MEMBER RICCARDELLA: Maybe your lecture
22 should be to the committee and not to the
23 presenters.

24 (Laughter.)

25 CHAIRMAN SUNSERI: You guys are doing

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1 good.

2 MS. MALIKOWSKI: That's fine. I mean I
3 think we've discussed the reason we already as far
4 as to just more for your reference we do have the
5 EFPY counts at the time of these inspections. This
6 was the 2010 OE from Cook 2.

7 As relating to UT, they did not do a UT
8 examination that time because they did not have a
9 qualified method and because it was one of these
10 challenging configurations. So they did what they
11 could with the availability at the time.

12 But I think to just jump to the
13 conclusions as we've been discussing, as you said,
14 the recent OE has been focused on -- and you said
15 not just downflow, but four-loop downflow as it was
16 kind of alluded to earlier, the larger reactor
17 design. They do have less bolts than say the
18 three-loop design has over a thousand. It's a
19 little over 800 for the four-loop. And then this
20 two has over 700. So there are design differences
21 that we see or design commonalities amongst the
22 most recent OE that do tend to give us some reason
23 to believe there's some commonalities to cause the
24 clustering that we've been discussing.

25 And we will, as we said, the most

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1 recent Cook 2 UT results and their failures
2 observed, we are as and Bryan will say, we're
3 following the industry to understand them.
4 Although I would say as you have the map in front
5 of you, it's not necessarily completely surprising
6 with that sea of red surrounding those replacement
7 bolts that cause the failures not to surprise them,
8 so to speak, but we will learn more from the --

9 MEMBER RICCARDELLA: I assume some of
10 those are going to be examined in the hot cell as
11 well, right?

12 MS. MALIKOWSKI: They are definitely
13 taking replacement bolts, failed replacement bolts
14 for analysis. Yes, this is the question of the
15 edge bolts, what they're going to do with them.
16 But yes, we want to learn from that.

17 MEMBER KIRCHNER: Just based on the
18 prior presentation, it looks like for Cook in that
19 time period that -- I hate to put precision on
20 this, but 6 bolts that had been replaced out of
21 about 50, so about 10 percent of the bolts were
22 cracked or indicated some problem 6 years later.
23 You changed from 345 to 316. So it seems to me
24 going back to my issue whether this is a design
25 problem that is more fluid mechanics, stress

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1 induced than it is a materials problem.

2 MR. RUDELL: And here's a theory --

3 CHAIRMAN SUNSERI: Please remember to
4 introduce yourself.

5 MR. RUDELL: Bernie Rudell.

6 CHAIRMAN SUNSERI: Thank yous.

7 MR. RUDELL: Here's a theory that goes
8 with the new bolt failures. It's basically -- I'll
9 sum it up, it's collateral damage associated with
10 the number of failed original bolts in the vicinity
11 of that -- of those new bolts and the flexure of
12 that plate. Now we probably will see a different
13 mode of failure to those new bolts when we look at
14 to prove our theory. And the same thing goes with
15 the edge bolts we saw there. We believe that's
16 collateral damage from that.

17 MEMBER KIRCHNER: Being formally from
18 Los Alamos, I would recommend a different
19 phraseology than collateral damage.

20 (Laughter.)

21 MEMBER RICCARDELLA: You know, I think
22 a significant point is that in 2010 when those
23 replacements were done, there was no ultrasonic
24 examinations done. And so they replaced some bolts
25 based on visual, but a lot of those other red spots

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1 around them might have been there at that time.

2 MEMBER BALLINGER: The replacement
3 bolts, did they have the same head design?

4 MR. RUDELL: Yes. Well, I would say
5 current replacement. Not the same as the
6 originals.

7 MEMBER BALLINGER: These are the
8 modified, supposedly less smaller stress
9 concentration?

10 MR. WILSON: Yes.

11 MS. MALIKOWSKI: Bryan has a picture of
12 that.

13 MR. WILSON: Yes, I have a picture of
14 that.

15 MS. MALIKOWSKI: So in order to get to
16 Bryan's discussion, just to pictorially show since
17 we don't show necessarily the EFPY for all the
18 other plants, and he'll describe as we kind of
19 already mentioned Tier 1 related to Westinghouse
20 Nuclear Safety Advisory Letter.

21 The inspections that have been done so
22 far domestically are kind of applied here and
23 Bernie will say we are developing an OE database to
24 help look and try and find any other trends amongst
25 various parameters. And this is just showing,

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1 based on the inspection timing what the number --
2 it says "assume degraded bolts" because they are
3 basically taking anything they couldn't inspect and
4 assuming it degraded just for the purposes here to
5 conservatively call them. But as you can see, for
6 at least the inspection guidance, other than our
7 four-loop downflow Tier 1 plants, the inspection
8 results do tend to show that we're finding -- I
9 think we have an appropriate inspection regime for
10 at least part of our population so while we are, as
11 we'll discuss, investigating what we need to alter
12 in our MRP guidance, there is at least some feeling
13 that we have some reasonable guidance for part of
14 the industry. So we're continuing to look at it
15 and we'll move forward.

16 I'll turn this over to Bryan so he can
17 continue into his discussion.

18 MR. WILSON: Hello, this is Bryan
19 Wilson, Westinghouse. So I guess -- I'm going to
20 have to hustle, so the point of my discussion here
21 is really going to be to provide a little bit of
22 explanation for some of the things I think Walter
23 has been kind of alluding to is what are the
24 mechanisms that are really leading off to causing
25 this degradation. And then pair that with what's

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1 the safety significance that we've evaluated as
2 part of our safety evaluation and then how led into
3 recommendations that were made through the NSAL to
4 the industry.

5 So first is the factors influencing
6 baffle-former bolt degradation. Jeff had covered a
7 lot of these, so the high points really are that
8 we've got bolts that are in a susceptible or an
9 area or a region that's susceptible to IASCC. And
10 that susceptibility is kind of common amongst
11 various plants but what we're seeing in the OE is a
12 differentiation from one plant to another. We're
13 seeing much larger failures in one plant than
14 another.

15 So the question is what's causing that
16 differentiation? One theory is stress. Stress is
17 the other contribution to propagating cracks. And
18 there's a lot of different things that impact
19 stress. I'd say some of the most important things
20 are one, the stress relaxation. Stress relaxation
21 is occurring in all of these baffle-former bolts or
22 the majority of them.

23 MEMBER BALLINGER: That stress
24 relaxation occurs most of it within five or so DPA?

25 MR. WILSON: Right.

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1 MEMBER BALLINGER: So that's basically
2 two years or thereabouts?

3 MR. WILSON: Right, so my point with
4 that is that once you get rid of that, these
5 external loads, externally-applied loads become
6 important. If you were to have a tight joint, then
7 we'd probably eliminate a lot of what we're talking
8 about here. So that's one key point.

9 The other is bolt design differences.
10 So head to shank transition radius, materials maybe
11 not so much because of our lack of data to support
12 that, but bolt length.

13 I think the question was asked earlier
14 about what the bolt length, how that got segregated
15 between the plants. A lot of the early plants did
16 use 347 bolt with a shorter shank and so some, I'd
17 say, not all of the two-loops. And all of the
18 four-loop downflows and some of the other four-
19 loops, there's not -- again, it's not across the
20 board that all the four-loops use these shorter
21 shanks. They started transitioning in later years
22 to a longer shank. But I'd say the early plants
23 were using these shorter shank bolts.

24 As you transition away, the bolt shanks
25 were going from like an inch and a half long to two

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1 to three inches long and stresses were coming way
2 down as a result because a lot of the stresses in
3 these bolts are a result of thermal expansion of
4 the plates basically, relative temperature between
5 the barrel and the plate itself, and baffle plate.

6 MEMBER RICCARDELLA: And swelling
7 differences.

8 MR. WILSON: And swelling differences.
9 Yes, there's a lot of other extraneous things, but
10 I'd say nominal stresses on the bolts are a result
11 of that.

12 The other factor influencing stress on
13 these bolts is the load, the hydraulic load on the
14 bolts. So this speaks to the downflow versus
15 upflow in the plant design. So four-loops, three-
16 loops, two-loops, the pressure across the plate
17 varies say consistently with the amount of flow,
18 total flow in the plant. So it's not an exact, for
19 instance, a four-loop plant, 50 DPA versus three-
20 loops 30 and two-loops 20, but it's that same kind
21 of trend. So that's one contributor, right? So
22 that naturally says four-loops generally have
23 higher load.

24 MEMBER RICCARDELLA: One thing that
25 surprised me is counter intuitive is that the

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1 three-loop plants have more bolts than the four-
2 loop plants?

3 MR. WILSON: That was exactly my next
4 point. So if you look at the bolt distribution on
5 a four-loop, versus a three-loop versus a two-loop,
6 the order is that four-loop -- or two-loops
7 actually have the least, the smallest plates,
8 right? Followed by four-loops, followed by three-
9 loops. Three-loops have considerably more bolts
10 than a four-loop.

11 So in a bolt per plate load
12 distribution, the four-loops generally see a
13 significantly higher load than either the two or
14 the three. So that also adds to the negative or
15 depending on your perspective, deposited for
16 identifying which ones are leading.

17 Other contributions are thermal, as I
18 mentioned. There's a thermal gradient across the
19 plate as well as a thermal gradient between the
20 baffle plate and the core barrel which causes say
21 more of a growth of the plate, relative growth
22 difference. So those are -- keep that in mind, I
23 guess.

24 Some other things that are affecting
25 the failures or failure, say propagation is

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1 clustering of bolts. So once one fails in a more
2 highly susceptible plant that has say a high
3 external load like a pressure differential, you
4 have a better likelihood or a higher likelihood for
5 load shed to the adjacent bolts. And then once you
6 get that load shed, you're increasing your
7 susceptibility to IASCC, you know, you're reducing
8 the critical flaw size, right, for a bolt if you're
9 looking at fracture mechanics base. So it all kind
10 of starts to trend in one replacement.

11 So on the opposite of that is bolt
12 replacement. Once you put bolt replacement, you're
13 affecting the load distributions for all the
14 different bolts that are in the system. So these
15 all have to be considered. It's just that it's a
16 very complex situation and a lot of things,
17 different things going on.

18 But I think if you boil down what the
19 deltas are between the plants and where we're
20 seeing the high number of failures, I think what
21 you're seeing is a trend towards the higher
22 pressure, the plants with higher differential
23 pressure which are downflow. And then four-loops
24 which generally have a smaller number of bolts than
25 say a three-loop or a two-loop. So those all seem

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1 to trend in a direction that we're -- that is
2 following the OE.

3 So what we're seeing from the OE is
4 three different failure patterns, right? One is
5 randomly distributed more IASEC is governing and
6 you're getting kind of -- failures are occurring
7 kind of in areas either you would expect because of
8 the high fluence or they are say more well
9 distributed and they can be representative from
10 statistical evaluations like a Weibull distribution
11 or something like that.

12 The next is dose related and this is
13 more like what maybe EDF is seeing where the
14 failures are say not necessarily cascading in
15 nature, but they're more say focused on areas of
16 high fluence, high load and maybe high amplitudes
17 of like fatigue loads, for instance, if you're
18 doing load follow.

19 And then you've got clustered which is
20 kind of what we're seeing, I think, at Indian
21 Point, Salem, Cook where you've got some failures
22 that look like they're just spreading from a
23 nucleus, right, and going out. And those are the
24 ones I would say are the most concerning from a
25 management -- a degradation management standpoint

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1 because those are ones that you want to make sure
2 you stay ahead of at the infantile stages so you
3 don't let them expand.

4 So I can get into cluster --

5 CHAIRMAN SUNSERI: Let me interject
6 here. I think based on the time, why don't you
7 skip ahead to the consequences and evaluations of
8 the baffle-bolt degradation because we kind of
9 heard this story that you're about to tell and we
10 might have more interest in some of the downstream
11 topics. I'm kind of reading ahead in your
12 presentation.

13 MR. WILSON: Excellent. That's fine.
14 I appreciate the suggestion.

15 So as I alluded to previously,
16 Westinghouse had conducted a safety evaluation
17 basically of the degraded condition looking at an
18 extreme condition, a condition at which was not --
19 did not have -- I said was well beyond the OE that
20 was being experienced to look at what the potential
21 of Part 21 reportability of this might be. And so
22 for the condition that we evaluated, we looked at
23 basically a quadrant of the baffle-former assembly
24 with all the bolts, all the baffle-former bolts
25 degraded. And the edge bolts were left. I would

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1 say in some state, we didn't necessarily define at
2 the time what degraded state those were in, but we
3 acknowledged that there's some overlapping of
4 plates that would create a simple supported edge
5 condition and the edge bolts would be in some
6 condition that they would also support that simply
7 supported condition, whether they're all there or
8 some random distribution of failures occurring
9 there as well. So that was say the basis for the
10 evaluation.

11 Things we looked at were impact on core
12 bypass, control rod insertability as a result of
13 plate deflections and impact with the fuel and fuel
14 assembly grid crush and core coolability. So for
15 the control rod insertability grid crush
16 evaluations, we looked at a dynamic analysis where
17 we basically took a loose plate or plate that only
18 had simple supports.

19 Yes, Peter? Oh, I'm sorry. I thought
20 you were raising your hand. Okay.

21 So we took a plate that was simply
22 supported, imposed the pressure distributions of a
23 LOCA on this plate and had models of the fuel
24 assembly stacks, you know, basically rose and
25 looked at how those fuel assemblies interacted with

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1 one another and how they interacted with the plate
2 to predict both what the peak deflections of the
3 fuel assemblies were at control rod locations and
4 also looked at what the grid deformation looked
5 like.

6 In those evaluations, what we found was
7 that the grid deformations were more I'd say
8 cellular in nature, so in an individual grid cell
9 unit you would have some sort of say small
10 deformation, shifting, making it more like a
11 parallelogram rather than a square. But the
12 overall configuration geometry didn't change such
13 that you would block flow. And the control
14 spacings didn't say get tremendously closer, much
15 closer to one another such that you would have
16 concerns from departure from nucleic boiling and
17 things like that. So that was in grid crush.

18 For control rod insertability we
19 looked at maximum deflections of the control or of
20 the fuel assembly after the event had occurred to
21 see if we can get the rods in in a bowed
22 configuration. And in that configuration, we also
23 looked at thimble tube stresses or guide tube
24 stresses I should say that -- to make sure those
25 didn't exceed allowables for the fuel assembly

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1 because maybe all bets are off after -- you know,
2 if those fracture, right?

3 So those evaluations showed that the
4 fuel did not go to an amount that would impact
5 control rod insertability. We have test data,
6 historical test data, where we looked at pulling
7 fuel assemblies, you know, by a significant amount
8 and inserting rods and found that for that
9 deflection that was applied and I won't state it
10 necessarily here, for that deflection that was
11 applied the control rod insertability times were
12 only impacted by .02 seconds and it was a
13 considerable amount of deflection.

14 So what we found was all of these
15 evaluations that we did assuming a loose baffle
16 plate, the fuel assembly, say bowing or lateral
17 deflection, didn't exceed those numbers that were
18 say bound by the test data that we had. So we felt
19 comfortable that in this extreme condition that the
20 fuel assembly, even in an bowed state would be an
21 acceptable level of bowed state and that the grids
22 would remain in a condition that were acceptable
23 for core cooling.

24 And so we looked then deeper into LOCA,
25 non-LOCA impacts on core coolability and safe

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1 shutdown margin and things like that. I would say
2 all came out positive with ample margin on those.
3 So the control rods would be able to fully insert
4 at all locations. There would be some amount of
5 grid deformation at peripheral assemblies as well
6 as some inboard assemblies, but to a lesser degree
7 and core coolability would largely remain
8 unaffected.

9 MEMBER RICCARDELLA: In the analysis,
10 the baffle plates actually impinge on the fuel
11 rods?

12 MR. WILSON: Yes, they push in.

13 MEMBER RICCARDELLA: Push in enough so
14 that your deflections are big enough.

15 MR. WILSON: Yes.

16 MEMBER RICCARDELLA: Okay.

17 MR. WILSON: The deflections are, I'd
18 say for that kind of a plate configuration, it's
19 long and narrow and thin, right? And it can push
20 in a good bit.

21 MEMBER SKILLMAN: What did you use as
22 the basis for the number of bolts that you did have
23 retaining load?

24 MR. WILSON: So we had zero baffle-
25 former bolts retaining load.

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1 MR. RUDELL: In a full quadrant.

2 MR. WILSON: In a full quadrant.

3 MR. RUDELL: Not just an octant, but
4 just one plate.

5 MEMBER SKILLMAN: Got it. Thanks.

6 MEMBER POWERS: From a hydraulic
7 colleagues' part of my mind rigorous in their
8 evaluation of such analyses, could you defend them
9 before that?

10 MR. WILSON: Could I defend them before
11 that?

12 MEMBER POWERS: Could you defend these
13 calculations before -- from a hydraulics'
14 community? That is, do you have enough
15 experimental data to say that you adequately
16 simulated?

17 MR. WILSON: I personally can't speak
18 to that, but I believe that yes, we do have
19 adequate data to support this.

20 CHAIRMAN SUNSERI: You had involvement
21 by your thermal hydraulics course?

22 MR. WILSON: Yes.

23 CHAIRMAN SUNSERI: I imagine. Okay.
24 So I really hate that --

25 MEMBER POWERS: What was the case? One

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1 from a hydraulicist is a very pleasant fellow. Two
2 is the problem.

3 (Laughter.)

4 CHAIRMAN SUNSERI: I hate to ask you to
5 do this, but we do have another subcommittee
6 meeting following this one, so we have to really
7 stick to the schedule and I apologize for rushing
8 you, so I'm going to give you five minutes to hit
9 your main points because we're going to allow some
10 public comment period here and I need to do that.
11 We may need to have some more committee follow-up
12 questions and that's going to take some time to get
13 through. So I apologize for putting you in there,
14 but we do have the slides, so we are able to read
15 it. So conclude what your main point is here.

16 MR. WILSON: Right. So I'll skip past
17 this, but a couple of other fuel-related things we
18 did look at is baffle jetting and loose parts as
19 well, but Jeff, I think, covered that rather well.

20 Now this led to communication to the
21 industry. So the industry was informed of all of
22 what's going on. All of our evaluations and I'd
23 say a culmination of what I talked about before
24 about likely cause of the issue, apparent cause of
25 the issue and what's leading to more susceptibility

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1 ranking of the plants.

2 We were able to say tier the plants to
3 address plants at an early enough time frame or as
4 soon as we can. The most susceptible ones were
5 addressed first and then progressively provide
6 recommendations as you decrease in susceptibility.

7 Let's see, so yes, so the intent was to
8 promote early identification of failures, as I
9 said. You want to find this as soon as possible to
10 prevent any expansion of the clustering.

11 And then we did allow freedom in our
12 NSAL recommendations for evaluating extent of
13 condition. We recognize that we don't know
14 everything at the beginning, so this is where MRP,
15 I think, picks up in looking at this issue more
16 holistically from the data that's being gathered so
17 that kind of speaks to the bottom. Two points
18 there that we're using lessons learned to further
19 grow on this topic.

20 I trust that you guys have maybe all
21 read the NSAL or have knowledge of the NSAL so I
22 won't go through, but essentially the big topic is
23 Tier 1 plants here that Tier 1A plants are doing UT
24 inspections at the next refueling outage and they
25 will all be completed by end of next year. So that

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1 is the near term.

2 There's a Tier 1 Bravo and the
3 differentiation here is really the head-to-shank
4 radius and the material difference. It's, I'd say,
5 prior experience. And so there's a noted, say
6 potentially less susceptibility for this plant. So
7 NSAL does say that those plants will need to do a
8 visual inspection and the idea there is that all of
9 the other plants, when they had significant
10 degradation had been able to find this through a
11 visual inspection. It's not an optimum inspection
12 necessarily, but it will identify if you've got say
13 large quantities of failures.

14 MEMBER RICCARDELLA: You've got seven
15 in the first group, seven units in the first group.

16 MR. WILSON: Yes.

17 MEMBER RICCARDELLA: How many in the
18 second group?

19 MR. WILSON: Two.

20 MEMBER RICCARDELLA: Oh, okay.

21 MR. WILSON: So then Tier 2, largely
22 Tier 2 has been inspected. So our recognizing
23 that, our guidance was really that those plants
24 should go back, consider the OE that we have now
25 and look at how that impacts what their inspection

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1 results and how they reacted to the issue or
2 reacted to their initial inspections. And then
3 adjust accordingly. And MRP went further with the
4 recommendations with this as well in NEI-308 space.

5 And then Tier 3 and Tier 4, there's
6 acknowledgment that there's, especially for
7 converted upflow plants as it could have been early
8 damage as a result of being downflow, but that has
9 maybe been say reduced or you know, say corrected
10 in the conversion upflow. So there's a kind of a
11 time limit. If you had been downflow for a long
12 period of time, then you would need to maybe take
13 action there.

14 MEMBER SKILLMAN: Bryan, how many Tier
15 3 plants are there, please?

16 MR. WILSON: Well, there's -- I don't
17 have -- I think a large number of them are actually
18 -- and there's really only one.

19 MS. ROSS-LEE: I think there's like
20 three Tier 3 plants. There's more than three.

21 MR. RUDELL: It goes beyond four-loop.
22 The first bullet there specifically, the four-loop
23 set, but there's a lot of three-loops.

24 MEMBER SKILLMAN: That are converted
25 upflow?

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1 MR. RUDELL: Yes.

2 MEMBER SKILLMAN: Thank you.

3 MR. WILSON: So that's -- oh, wait, I
4 don't want to skip my picture here. So here's the
5 replacement bolt, right? So as we've discussed
6 before, some of the -- the real design differences,
7 the change in the material, but I'd say as far as
8 improved susceptibility that one is -- I think the
9 jury is still out on that one necessarily. The
10 semi-parabolic head to shank transition fillet is
11 really the key item there. And then the other
12 changes or things you see on this bolt design are
13 really related to install, ability to install the
14 bolt and crimp it without welding to an irradiated
15 baffle plate.

16 MR. RUDELL: And inspectability.

17 MR. WILSON: Right, and so the flat
18 head here allows for ease of inspectability.

19 MEMBER RICCARDELLA: That looks like a
20 relatively short shank. Is that prototypical?

21 MR. WILSON: Yes, that's standard for
22 this short bolt. It's a really short shank.

23 MEMBER RICCARDELLA: Okay.

24 CHAIRMAN SUNSERI: All right, anything
25 else?

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1 MR. WILSON: Bernie, do you have
2 anything to add?

3 MR. RUDELL: I think you summarized
4 everything --

5 CHAIRMAN SUNSERI: Because we need to
6 open up the phone lines here.

7 MR. RUDELL: I think I said everything
8 that was in the other slides with regards to
9 forming the focus group and working through that.
10 That's in the rest of the slides.

11 CHAIRMAN SUNSERI: Okay, well, we
12 appreciate your interaction with the committee.
13 It's been really interesting.

14 So at this time, I'm going to ask for
15 the phone line to be open and I hope that they are
16 open. So if I could have somebody on the phone
17 line at least speak something so we can confirm the
18 phone line is open and once we confirm the phone
19 line is open, we'll ask for comments. Is anybody
20 out there?

21 MR. LEWIS: Marvin Lewis, a member of
22 the public.

23 CHAIRMAN SUNSERI: Okay, great. So the
24 phone lines are open. At this point, I will ask
25 for any comments from the people on the line.

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1 MR. LEWIS: Marvin Lewis.

2 CHAIRMAN SUNSERI: Yes, go ahead.

3 MR. LEWIS: Look, I'm not saying that
4 the testing and the statistics cited are in any way
5 wrong or screwed up or anything else.

6 In the late 1950s, we had a place
7 called Shoshone in Simi Valley of Los Angeles
8 County. And it has a very similar problem. A
9 baffle plate broke loose. I don't know why. I
10 can't remember that out of my head, but 60 years is
11 a long time, 70 years, almost. Yes, over 60 years.
12 It was a long time to remember back to that, but I
13 seem to remember that just about everything I heard
14 today was said before we had that problem at
15 Shoshone and I'm saying hey, 60 years and you've
16 got the same problem? Come on. Don't we ever
17 progress? Thank you.

18 CHAIRMAN SUNSERI: Thank you. Anyone
19 else? Anybody else on the phone line?

20 All right, let's close the phone line
21 then. And we'll turn to the audience now.

22 MS. CURRAN: Good morning. I'm Diane
23 Curran representing Riverkeeper. In the Indian
24 Point license renewal proceeding, we have an
25 admitted contention, several admitted contentions

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1 in conjunction with the New York State Attorney
2 General's Office that deal with issues related to
3 aging equipment.

4 I really appreciate the presentations
5 this morning. They've been very helpful, very
6 informative. And I have a concern that I'd like to
7 express for Riverkeeper about what appears to be a
8 lack of a plan to include consideration of the root
9 cause analyses for plants other than D.C. Cook. I
10 am thinking of page 37 of your presentation, Mr.
11 Poehler, where you mentioned that the NRC is going
12 to be following up with the D.C. Cook root cause
13 analysis and I would just like to confirm that I'm
14 assuming that root cause analysis will be done --
15 well, one has been done for Indian Point and I
16 don't know whether one has been done for Salem, but
17 I would think that these would be very important
18 studies that should be looked at together and
19 integrated because it's clear that there's a lot of
20 questions about what causes the degradation of
21 these bolts and I wonder if I could confirm that
22 with you and also see if these reports are all
23 going to be submitted to the NRC.

24 CHAIRMAN SUNSERI: Unfortunately, this
25 is not an opportunity to interact. It's just an

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1 opportunity to make a comment. So we understand
2 your concern has been expressed and is there
3 anything else you would like to offer?

4 MS. CURRAN: Well, I was hoping since I
5 seem to be the only person that is commenting that
6 I could have a little interaction.

7 CHAIRMAN SUNSERI: We're obligated by
8 the federal regulatory rules for this meeting, so I
9 apologize for stifling that.

10 MS. CURRAN: Thank you.

11 CHAIRMAN SUNSERI: Any other members in
12 the audience would like to make a comment?

13 All right, so let's go around the room
14 here and hear from the ACRS members any further
15 comments. And we'll start with Ron.

16 MEMBER BALLINGER: Thank you very much
17 for the presentations. They're very informative
18 and it brings everybody up to date on what's going
19 on. So I thought it was a great job and thank you
20 very much.

21 CHAIRMAN SUNSERI: Pete?

22 MEMBER RICCARDELLA: No comments other
23 than to echo what Ron said.

24 CHAIRMAN SUNSERI: Dick?

25 MEMBER SKILLMAN: No further comment.

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1 Thank you.

2 CHAIRMAN SUNSERI: Dana?

3 MEMBER POWERS: Well, of course the
4 presentations were very nice on the specific issue.
5 And if we look at the specific issue, it's moved
6 along since the first findings in France which may
7 to some people seem slow, but for those of us that
8 worry about some screen blockage, it's been at a
9 blindingly fast pace.

10 What I expressed concern about is
11 moving forward beyond what's now planned. And for
12 that to happen within the NRC, we need to have a
13 nexus to the protection of public health and
14 safety. Some very conservative calculations were
15 done following the processes at the NRC and those
16 are fine. I have no troubles with that. That's
17 probably the only thing you can do.

18 The industry has indicated, however,
19 they can do calculations that are substantially
20 more rigorous I would say. Whether those are
21 defensible and in front of my thermal hydraulic
22 colleagues I don't know. They're rather picky.
23 But it's that kind of analysis we're going to have
24 to do to show that there is a nexus to the
25 protection of public health and safety that

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1 mandates continued NRC following of this issue
2 beyond what's planned now.

3 As a parenthetical note, we continue to
4 see that NDE techniques were not in a state of high
5 reliability. This is certainly not an issue for
6 the NRC to take on and may not even be an issue for
7 the nuclear industry to take on, certainly show
8 where the entire burden. I think this is a
9 national issue that we need to recommend on a
10 national basis as something to focus for the
11 private sector, the academic sector and the
12 government sector to take on.

13 CHAIRMAN SUNSERI: Thanks, Dana. John
14 Stetkar?

15 MEMBER STETKAR: Nothing at all. Thank
16 you.

17 CHAIRMAN SUNSERI: Walt.

18 MEMBER KIRCHNER: Thank you for the
19 presentations. I can't pass up on Dana's earlier
20 comments. I think I'm the only Thermal Hydraulics
21 Subcommittee member here.

22 MEMBER POWERS: And proof that having
23 one is a pleasant experience.

24 MEMBER KIRCHNER: Yes, exactly. Oh,
25 two. So it did turn out pleasant. It might be

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1 worth considering hearing more detail about the
2 actual calculations that are done, but I'll leave
3 that to the chair of the Thermal Hydraulics
4 Subcommittee.

5 MEMBER POWERS: Oh, you guys are in
6 trouble now.

7 CHAIRMAN SUNSERI: I would like to
8 extend my appreciation to both the NRC and the
9 industry representatives here for the informative
10 presentation. Looks like there's still plenty of
11 work ahead. I'm going to speak in advance for the
12 subcommittee, but I would imagine that we'll be
13 interested in the hot-cell work and examinations
14 that are forthcoming and we'll likely be seeking a
15 further update as more information becomes
16 available in the future.

17 So thank you and at this point we will
18 close this meeting.

19 (Whereupon, the above-entitled matter
20 went off the record at 11:55 a.m.)

21

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U. S. Nuclear Regulatory Commission

Recent Operating Experience with Baffle-Former Bolt Degradation

Jeffrey C. Poehler

**Office of Nuclear Reactor Regulation
Division of Engineering**

**Advisory Committee on Reactor Safeguards
Meeting of the Subcommittee on Metallurgy & Reactor Fuels**

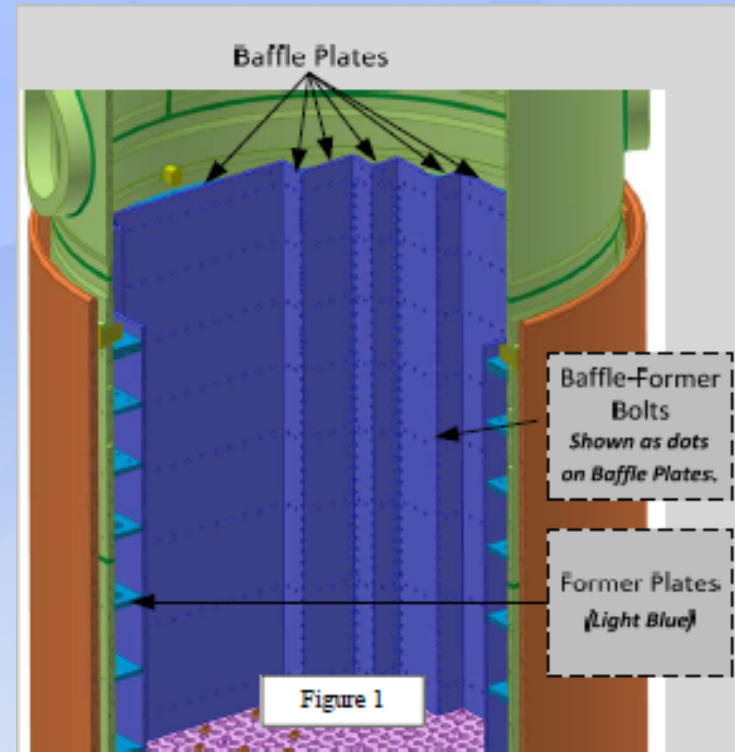
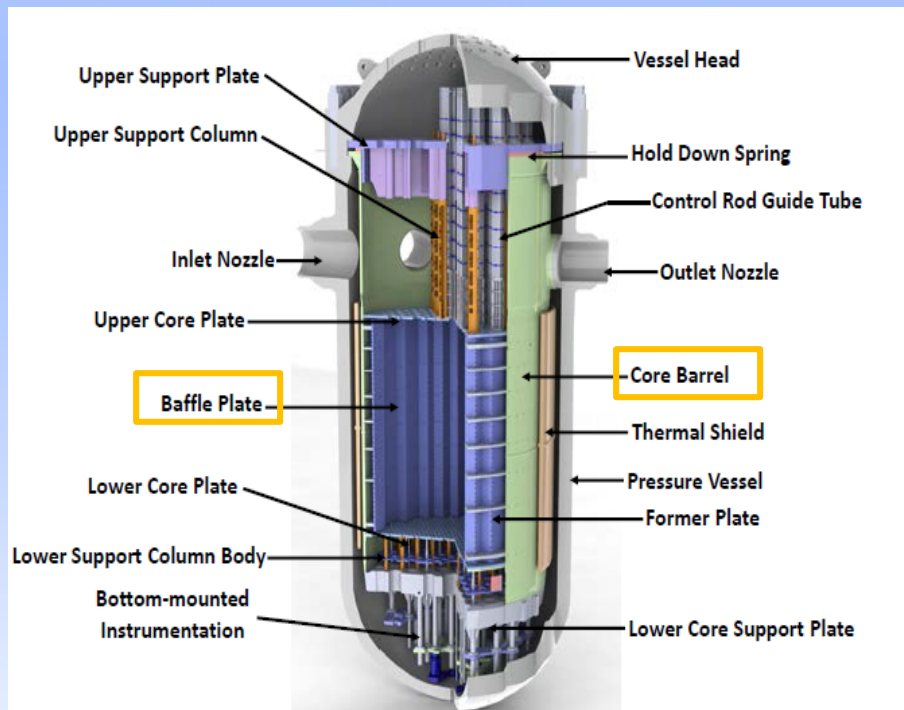
November 16, 2016

Protecting People and the Environment

- 1. Introduction - Objectives**
- 2. Design, Functions and Materials of PWR Internals, Baffle-Former Assembly, and Baffle-Former Bolts**
- 3. Potential Consequences of Baffle-former Bolt Degradation**
- 4. History of BFB Degradation**
- 5. Factors Influencing Baffle-Former Bolt Degradation**
- 6. Bolt Inspection and Replacement**
- 7. Evaluation of Baffle-Former Bolt Degradation**
- 8. NRC Response**
- 9. Future Activities for NRC**



Design and Functions of the Baffle-former Assembly



Function of baffle-former assembly is to direct coolant flow through the core. It also provides lateral support to the core during a seismic event or loss-of-coolant accident (LOCA).



Design and Functions of the Baffle-former Assembly

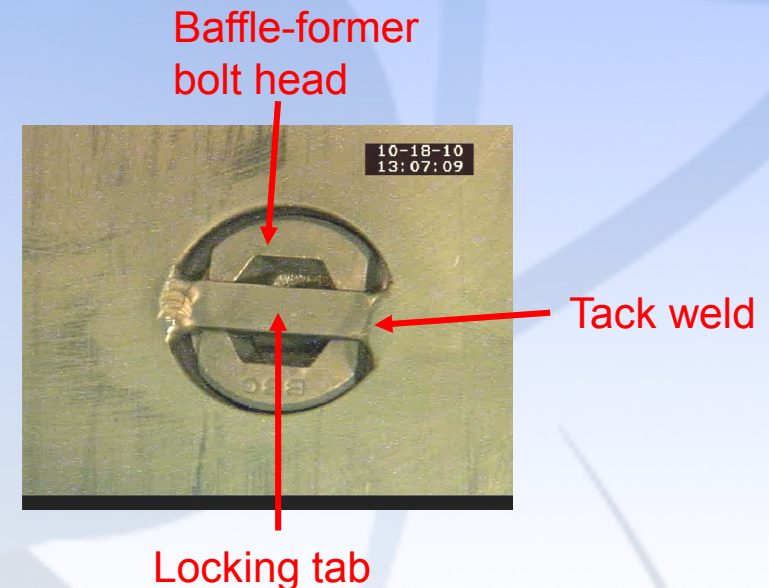
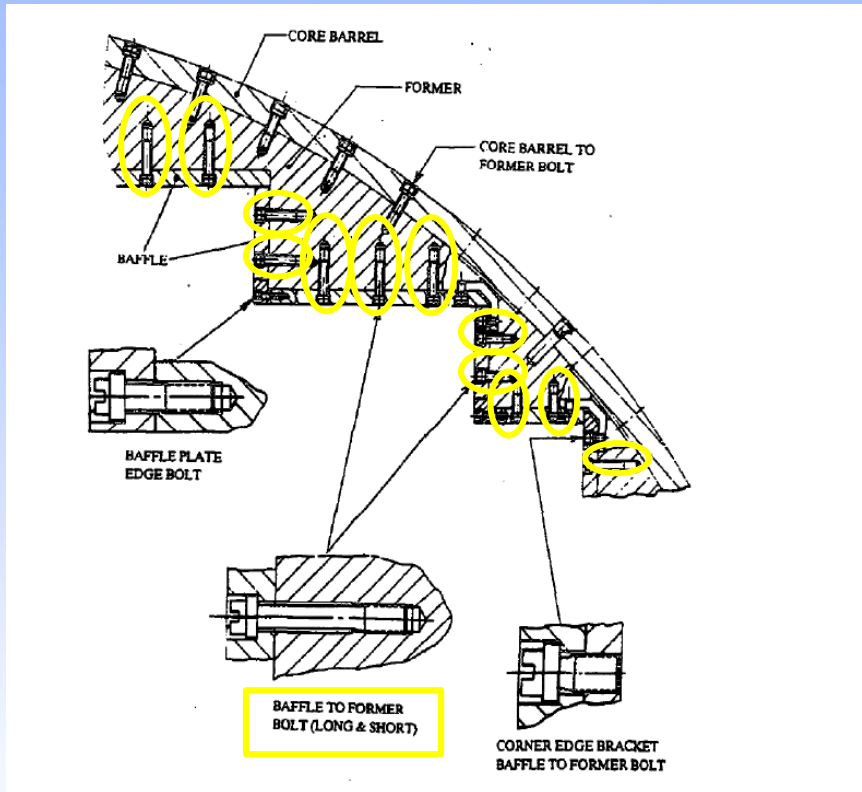


Looking down into the core barrel of a Westinghouse-design PWR



Design and Functions of the Baffle-former Assembly - Design of Baffle-former bolts

- Stainless steel bolts are 5/8" dia. x ~2" long and attach the baffle plates to the former plates to form the baffle-former assembly.





Design and Functions of the Baffle-former Assembly - Baffle-former Bolt Materials

- **Westinghouse (W) plants:**
 - Type 347 stainless steel
 - Most older Westinghouse plants
 - Bolt design has sharper head-to-shank radius and shorter shank than in Type 316 cold-worked bolts.
 - Type 316 cold-worked stainless steel
 - Newer Westinghouse plants
 - All replacement bolts
- **Other NSSS designs**
 - B&W plants use Type 304
 - CE plants use annealed Type 316 (2 plants – others have welded core shroud).



Potential Consequences of Baffle-Former Bolt Degradation – Baffle Plate Movement

- Large numbers of degraded baffle-former bolts could allow detachment or deflection of baffle plates, particularly during a LOCA or seismic event.
- Plates could impact peripheral fuel assemblies, potentially causing grid crush and localized fuel cladding damage.
- In plants with control rods in peripheral locations, plate impact could jeopardize capability to insert these rods .
- Intact baffle-edge bolts would help mitigate plate detachment or deflection.
- For localized damage to peripheral fuel assemblies, a coolable geometry evaluation can be performed.



Potential Consequences of Baffle-Former Bolt Degradation – Baffle Jetting

- **Baffle jetting is flow leakage through gaps between adjacent plates.**
- **Function of baffle-edge bolts is to ensure baffle plate integrity which prevents baffle jetting.**
- **Flow leakage causes flow-induced vibration of fuel pins resulting in localized fuel cladding damage, in some cases breaching cladding.**
- **Reactor coolant activity monitoring can detect increases in coolant activity that may be indicative of fuel damage.**



Potential Consequences of Baffle-Former Bolt Degradation – Loose Parts

- Bolt heads and locking bars can become loose parts if bolts completely fracture.
- The clearances between the baffle plates and fuel assemblies are very small, which would tend to prevent bolt heads from escaping until the reactor is defueled.
- Likely result of loose bolt heads is fretting causing localized fuel cladding damage.
- Due to small size, it is unlikely that a few failed bolts would be detected by the loose part monitor.
- Baffle plates are unlikely to detach during normal operation, but if they did, potential for travel is limited by tight clearances and large size of plates.



History of Baffle-Former Bolt Degradation – Early History

- **First identified in late 1980's in European plants**
- **French 900mW CPO Plants**
 - 6 plants found between 1% and 11% of bolts degraded
- **Belgian plants**
 - One 3-loop Framatome 900 mW design performed 5 examinations between 1991 and 2014 finding a total of 74 bolts degraded or uninterpretable.
 - Three other plants performed one UT examination each, finding a handful of degraded bolts.
- **Mechanism for degradation is irradiation assisted stress corrosion cracking (IASCC).**
- **NRC issued Information Notice 98-11 to alert U.S. plant operators.**
- **US Industry initiated a program which included pilot inspections of baffle-former bolts at several plants.**



History of Baffle-Former Bolt Degradation – US Pilot Plant Inspections

- **Two 2-loop downflow plants with Type 347 bolts (1998-1999)**
 - Plants found 7-10% of bolts degraded
 - Replaced degraded bolts, one plant replaced additional non-degraded bolts
 - Tensile testing of removed bolts performed at one unit, indicated number of defective bolts was less than indicated by UT results.
- **Two 3-loop downflow plants with Type 316 bolts (1998-1999)**
 - UT examined essentially all bolts – no indications
 - Pre-emptive replacement of >200 bolts each unit
- **One B&W plant (2005)**
 - No indications found



History of Baffle-Former Bolt Degradation – MRP-227-A

- **2000-2011, Most plants applying for license renewal made commitment to implement industry RVI program when it was issued.**
- **Industry program (MRP-227, Rev. 0) under review by staff 2009-2011.**
- **Industry program was approved by NRC staff in 2011 (MRP-227-A).**



History of Baffle-Former Bolt Degradation – MRP-227-A Inspection Requirements for Baffle- Former Bolts

- **Ultrasonic (UT) Examination**
- **Initial (baseline) Examination**
 - **Westinghouse and CE: 100% of bolts between 25-35 effective full power years**
 - **B&W: 100% of accessible bolts no later than two refueling outages from the beginning of the license renewal period**
- **Inspect every 10 years thereafter (or sooner if required by analysis of any observed degradation).**
- **All PWRs with baffle-former bolts must perform these inspections.**



History of Baffle-Former Bolt Degradation — D.C. Cook, Unit 2 (2010)

- D.C. Cook, Unit 2 is a 4-loop downflow plant with Type 347 bolts (832 total baffle-former bolts).
- Eighteen bolts had visual signs of failure.
- Licensee replaced a total of 52 bolts with Type 316 SS, most on one large baffle plate, 42 found to be cracked.
- To establish extent of condition, on the three similar (large) baffle plates, licensee:
 - performed VT-3, no degradation
 - Tensile tested one bolt from each plate, no degradation
- No UT performed
- Two bolts locations left vacant .
- Westinghouse issued Technical Bulletin TB-12-5 to alert licensees.




History of Baffle-Former Bolt Degradation – Inspections under MRP-227-A (2011-2015)

- **Westinghouse 2-loop (Type 347 bolts, 34 EFPY), five reactors**
 - Maximum defective bolts was 10.3%, 34 EFPY
 - One repeat inspection (plant inspected 1998), 15 additional degraded bolts, 2.7% of original bolts
 - One 2-loop plant that inspected in 1998 did a partial UT examination and replacement.
- **Westinghouse 3-loop (Type 347 bolts, 30-32 EFPY), four reactors**
 - UT examination of 100% of bolts at three units (1088 bolts each), number of potentially degraded bolts was 1, 2 and 8.
 - Partial UT examination of 305/1088 bolts at one unit, stopped due to equipment problems, no indications
- **B&W (Type 304 bolts, 30-32 EFPY) – Three reactors inspected, no more than 4 bolts with indications in each.**
- **CE – (Type 316 bolts, 27-28 EFPY) No inspections to date**



History of Baffle-Former Bolt Degradation – Indian Point, Unit 2

- IP2 is a 4-loop, downflow plant with Type 347 bolts
- During Spring 2016 refueling outage, IP2 conducted MRP-227-A inspection per license renewal commitment.
- Visual examination of 1232 baffle-edge bolts, all acceptable.
- UT and visual examination of 832 baffle-former bolts
 - 227 potentially degraded baffle-former bolts identified
 - 182 ultrasonic testing failures
 - 31 visually identified as protruding
 - 14 inaccessible, conservatively assumed failed



History of Baffle-Former Bolt Degradation – Indian Point, Unit 2 Corrective Actions

- **Indian Point Unit 2 (IP2)**
 - Replaced 278 baffle-former bolts (227 potentially degraded + 51 more to provide margin) with Type 316 SS
 - Completed analysis to support baffle-former assembly return to service - inspected by Region 1
 - Bolts sent to laboratory for testing to support root cause.
- **Indian Point Unit 3 (IP3)**
 - Operability evaluation of baffle-former assembly considering information from IP2 and Salem 1
 - Reschedule future baffle bolt examinations from 2019 to 2017



History of Baffle-Former Bolt Degradation – Salem Unit 1

- Salem, Unit 1 is a 4-loop, downflow plant with Type 347 bolts.
- During Spring 2016 refueling outage, licensee was conducting augmented visual inspection of baffle-former bolts due to known degradation issues (832 total baffle-former bolts).
- Identified 11 bolts cracked at head, 9 had visually cracked lock bar welds, 19 bolts protruding from counterbore
- Follow up UT of remaining baffle-former bolts determined 135 bolts were potentially degraded, plus 16 unable to be tested.
- Overall, ~190 bolts identified as needing replacement
- Significant clustering of degraded bolts in several octants
- No baffle-edge bolt degradation observed



History of Baffle-Former Bolt Degradation – Salem, Unit 1 Corrective Actions

- **Salem Unit 1**
 - 189 bolts replaced w/Type 316 SS
 - Analyzing selected bolts to confirm IASCC
 - Minimum bolting pattern analysis performed to determine replacement scope and justify operation for 1 cycle prior to re-inspection
- **Salem Unit 2**
 - Operability determination based on extent of condition from Unit 1
 - UT inspection of all bolts scheduled for spring 2017 (moved up from 2026)

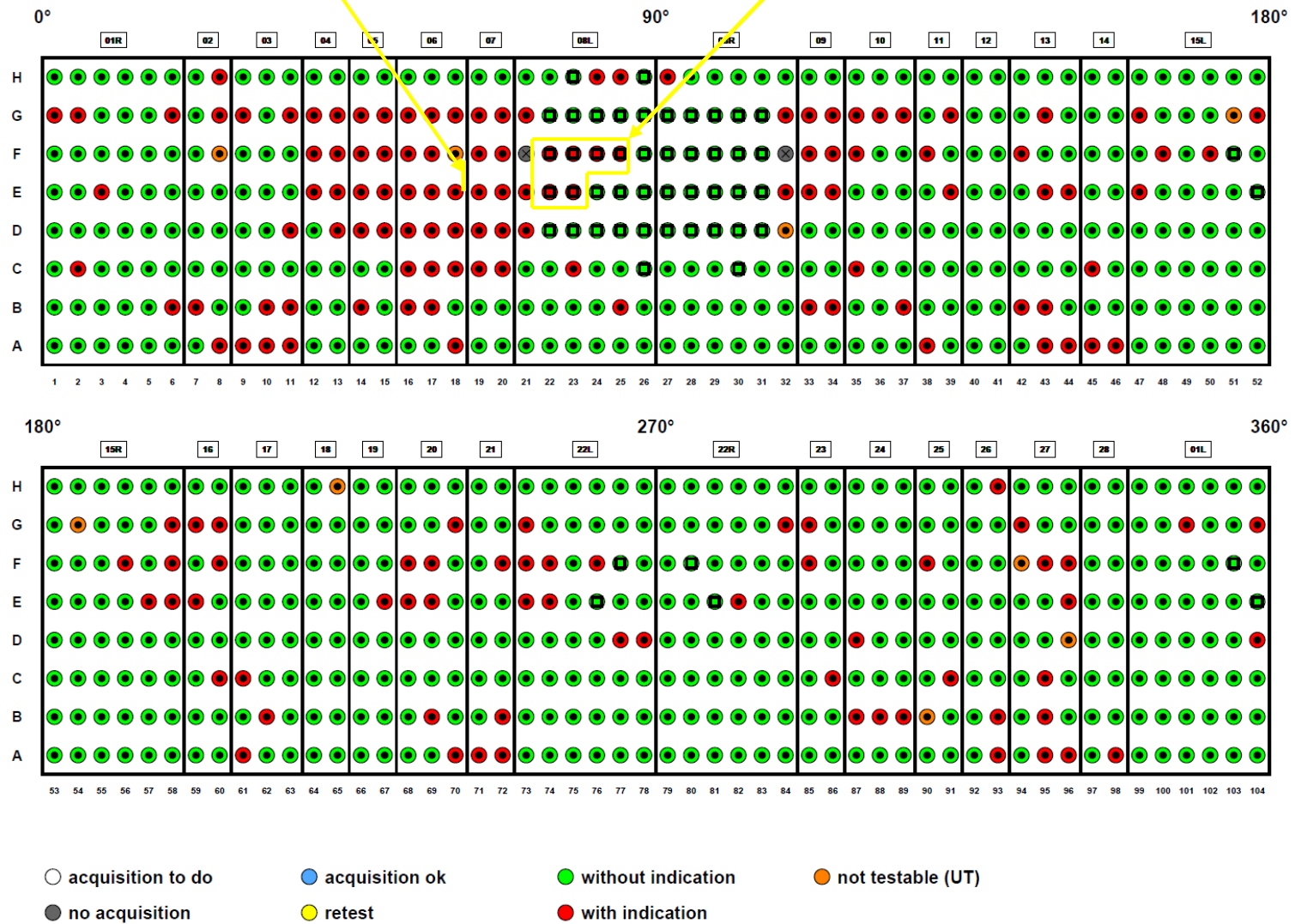


History of Baffle-Former Bolt Degradation – D.C. Cook, Unit 2 (2016)

- During October 2016, D.C. Cook, Unit 2 performed UT examination of baffle-former bolts (832 total) on accelerated schedule in accordance with MRP interim guidance.
- Total of 179 potentially degraded bolts
 - 170 with UT indications
 - 9 untestable bolts
- 2 vacant bolt locations from 2010
- Six (6) replacement bolts installed in 2010 had indications.
- At least one vacant bolt location correlated with a damaged fuel assembly.
- Visual examination of baffle-edge bolts found 5 degraded bolts.

Location of Degraded Edge Bolts

Degraded Replacement Bolts



As-Found Condition of D.C. Cook, Unit 2 Baffle-Former Bolts Fall, 2016 Refueling Outage



History of Baffle-Former Bolt Degradation – D.C. Cook, Unit 2 (2016) – Corrective Actions

- **Replace minimum of 181 bolts w/type 316 SS - all potentially degraded bolts (179) plus missing bolts (2), plus additional bolts up to 201 total as time permits**
- **Indications in replacement bolts will be further investigated.**
 - Previous plants that have re-inspected replacement bolts in service for 10-15 years found no indications.
 - Replacement bolts will be sent for laboratory analysis.
 - Performing sensitivity analysis to explore the effects on replacement bolt stress from failed original bolts in vicinity.
- **Corrective actions for baffle-edge bolts to be determined.**



Factors Influencing Baffle-Former Bolt Degradation – Neutron Fluence

- Austenitic stainless steels are normally resistant to SCC in a PWR environment.
- With high fluence, grain boundaries changes occur.
 - Neutron fluence threshold for IASCC is $\geq 2 \times 10^{21} \text{ n/cm}^2$ (3 dpa) - Baffle plates and bolts receive up to 75 dpa in 60 years.
- Patterns of bolt degradation in IP2, Salem 1, and Cook 2 do not correlate with highest fluence locations in the core.
 - 2-loop and 3-loop plants also had similar or higher fluence levels but fewer degraded bolts.
- Switch to a low-leakage core design will reduce flux to bolts, may slow initiation of new IASCC cracks.

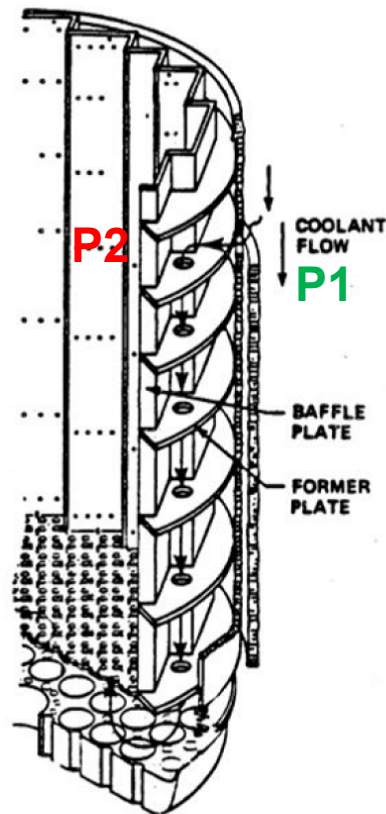


Factors Influencing Baffle-Former Bolt Degradation - Stress

- **Stresses on baffle-former bolts are from a variety of sources:**
 - Bolt preload stresses
 - Irradiation assisted stress relaxation
 - Void swelling of baffle plates
 - Differential pressure - greater in “downflow” than in “upflow”
 - Number of bolts per plate area
 - Bolt geometry –head-to-shank radius
- **Fatigue loads may have an influence.**
 - Affected by operating history – number of transients



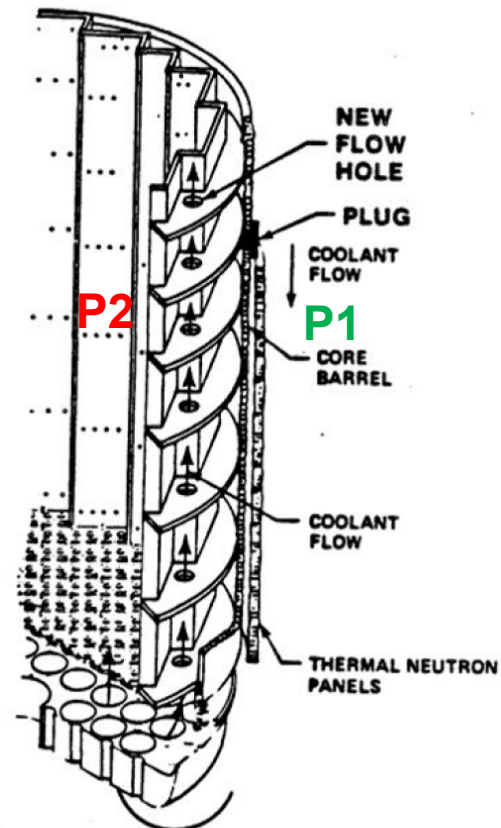
Factors Influencing Baffle-Former Bolt Degradation - “Downflow” vs. “Upflow”



DOWNFLOW
CONFIGURATION

$$P1 > P2$$

Tries to force baffle plate
inward = higher stress on bolts



UPFLOW
CONFIGURATION

$$P1 \approx P2$$

Lower stress on bolts



Factors Influencing Baffle-Former Bolt Degradation – Stress (Clustering)

- **Baffle-former bolts initially crack randomly.**
- **Failure of a bolt leads to more load being carried by adjacent bolts.**
- **Over several operating cycles, this can cause the adjacent bolts to crack leading to clusters of failed bolts (“unzippering”).**
- **Observed in French plants in successive examinations**
- **Severe clustering seen at Salem, Unit 1**



Factors Influencing Baffle-Former Bolt Degradation - Summary

- Degradation of baffle-former bolts involves a complex interaction of stress, neutron fluence, and bolt material/design
- Other aging mechanisms, such as void swelling and irradiation assisted stress relaxation influence IASCC of bolts
- Industry is developing predictive models for baffle-former bolt degradation accounting for neutron fluence, stress, and material
- Higher susceptibility to degradation seems more related to stress differences rather than fluence



Bolt Inspection and Replacement – Nondestructive Examination

- **Ultrasonic examination (UT)**
 - Demonstrated for flaw detection only, not sizing
 - Any bolt with a detected cracklike indication is called defective.
- **Visual examination (VT-3)**
 - Not specified by MRP-227-A for baffle-former bolts, but some plants have performed voluntarily in response to OE
 - Specified for baffle-edge bolts
 - Can detect evidence of failed bolts such as displaced lock bars, protruding or missing bolt heads
 - Evidence of failed bolts has also been detected by non-VT-3 visual inspections.



Bolt Inspection and Replacement – Replacement

- **Removal**
 - Many bolts can be removed intact once lock bar is cut.
 - Broken shanks can sometimes be removed mechanically but may require electro-discharge machining (EDM).
- **Replacement**
 - Replacement bolt design uses an expandable locking cup so no welding on highly irradiated baffle plate material is necessary.
 - Replacement bolts are cold-worked Type 316 stainless steel.
 - Replacement bolts have improved geometry to reduce stress at the head-to-shank transition.



Evaluation of Baffle-Former Bolt Degradation – Acceptable Bolt Pattern Analyses

- **WCAP-15029-P-A describes the NRC- approved generic methodology for determining acceptable patterns of intact baffle-former bolts.**
- **Uses the MULTIFLEX computer code to determine accident loadings**
- **Acceptance criteria include bolt stresses, fuel grid impact loads, momentum flux, fatigue and core bypass flow.**
- **When evaluating as-found bolt degradation, any degraded bolt is assumed to carry no load.**
- **Irradiated material properties are used for bolts.**
- **Plants use this methodology to evaluate as-found conditions and potential replacement patterns.**



Evaluation of Baffle-Former Bolt Degradation – Coolable Geometry

- In some cases, as-found degradation may not meet stress and fuel grid impact criteria.
- If fuel grid impact criteria are exceeded, may need to demonstrate a coolable geometry with some damage to peripheral fuel assemblies
- WCAP-15029-P-A provides some guidance.



Evaluation of Baffle-Former Bolt Degradation – Reinspection Interval

- **WCAP-17096-NP-A, “Reactor Internals Acceptance Criteria Methodology and Data Requirements,” provides guidance for engineering evaluation of baffle-former bolt degradation.**
 - **Numerical margin consists of additional bolts over and above the number in the minimum bolting pattern.**
 - **If the number of degraded bolts is less than half the margin, may reinspect in ten years.**
 - **If the number of degraded bolts is greater than half the margin, a different reinspection interval must be justified.**
- **Plants with large numbers of degraded bolts would not have met the WCAP-17096-NP-A criteria so replaced all bolts to restore full structural margin.**
- **Industry is developing models for failure rates of baffle-former bolts – need reinspections of bolts at < 10 year interval to establish.**



NRC Response – Regional Inspections

- The NRC staff performed targeted inspections at Indian Point and Salem and is performing a similar inspection at D.C. Cook.
- Inspections focused on:
 - NDE quality and accuracy (VT, UT)
 - Corrective actions, including evaluation of operating units
 - Adequacy of replacement bolt pattern, including margin for additional failures during next cycle
- Results of the NRC inspections are documented in publically available inspection reports.
- Regional inspectors engaging with other plants with regard to operability evaluations and plans for upcoming outages.



NRC Response – LIC-504

- **Evaluated four options,**
 1. Immediate shutdown and inspection;
 2. Inspection next refueling outage;
 3. Generic communication;
 4. Maintain status quo
- **Acceptable options must meet five criteria:**
 1. Compliance with existing regulations;
 2. Consistency with the defense-in-depth philosophy;
 3. Maintenance of adequate safety margins;
 4. Demonstration of acceptable levels of risk;
 5. Implementation of defined performance measurement strategies



NRC Response – LIC-504 - Results

- Risk met LIC-504 criteria of $CDF < 1 \times 10^{-3}$ and $LERF < 1 \times 10^{-4}$
 - Low frequency of large and medium LOCAs results in low CDF due to LOCA
 - Seismic risk assessment performed using bounding seismic hazard curve for U.S. based on recent updated seismic hazard submittals. Seismic assessment assumed 75% reduction in load capacity for baffle-former bolts, much greater than observed in any plant.
- Determined both Options 1 and 2 meet the five criteria of LIC-504: Options 3 and 4 have more risk uncertainty
- Option 1, immediate shutdown, places an unnecessary burden on licensees, thus Option 2 was recommended.
- Interim industry guidance effectively implements Option 2.



NRC Response – Operating Experience Summary

- Based on NRC staff review of operating experience, preliminary conclusion is that Westinghouse 4-loop design, downflow plants with Type 347 bolts are more susceptible to baffle-former bolt degradation than other PWR designs.
- Plants in this group are:
 - D.C. Cook, Units 1 and 2
 - Diablo Canyon, Unit 1
 - Indian Point, Units 2 and 3
 - Salem, Units 1 and 2
- EPRI MRP Interim Guidance calls for UT inspection of all baffle-former bolts at the next refueling outage for these plants (designated Tier 1a). The NRC is monitoring inspections and other actions at these plants.
- The immediate safety concern for these plants is addressed by the LIC-504 evaluation.



NRC Response – Future Activities

- **Following root cause investigation at D.C. Cook 2, with focus on cause of degradation of replacement bolts and baffle-edge bolts**
- **Will determine if the LIC-504 requires revision based on new developments at D.C. Cook, Unit 2**
- **Continue to engage with industry focus group, especially on root cause from the three plants. Discuss with industry if changes to interim guidance are necessary**
- **Develop Information Notice**
- **Document assessment of MRP interim guidance**
- **Determine if changes to MRP-227-A guidance are needed**

NRC – ACRS Metallurgy Subcommittee Briefing

Bernie Rudell, MRP Chair, Exelon

Heather Malikowski, PWROG MSC Chair, Exelon

Tim Wells, BFB Focus Group Chair, Southern

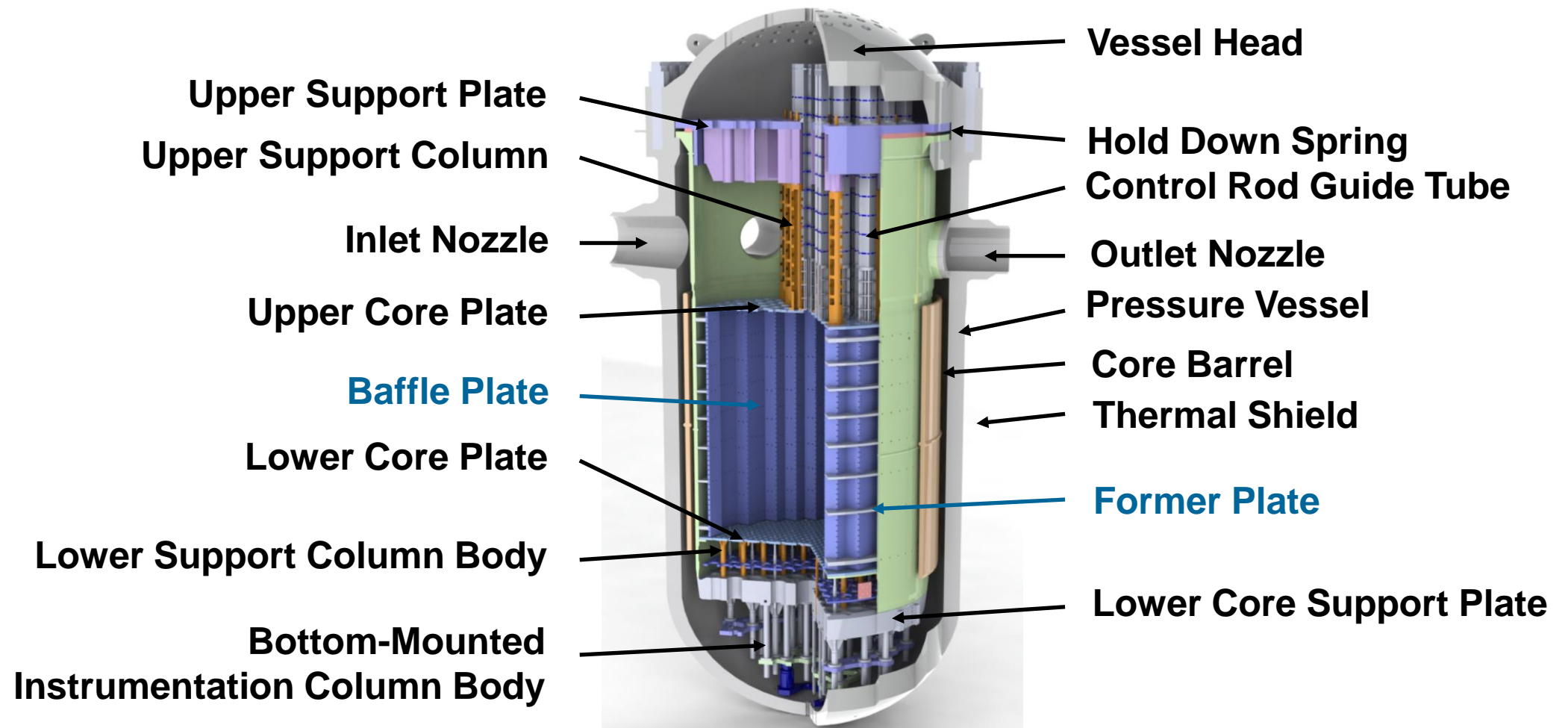
Kyle Amberge, Project Manager, EPRI

Bryan Wilson, Fellow Engineer, Westinghouse-PWROG

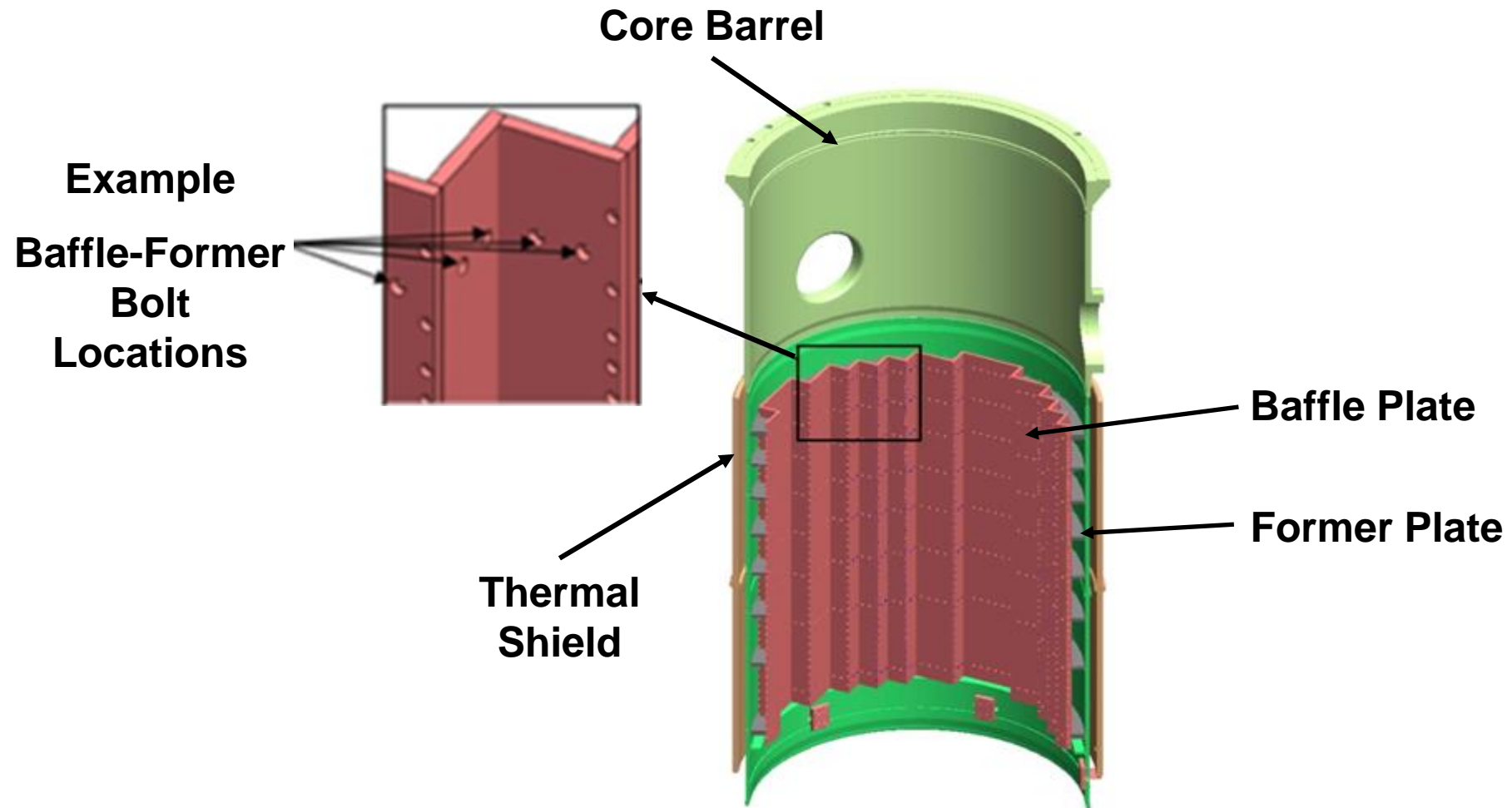
Rockville, MD, November 16, 2016



Westinghouse NSSS Internals



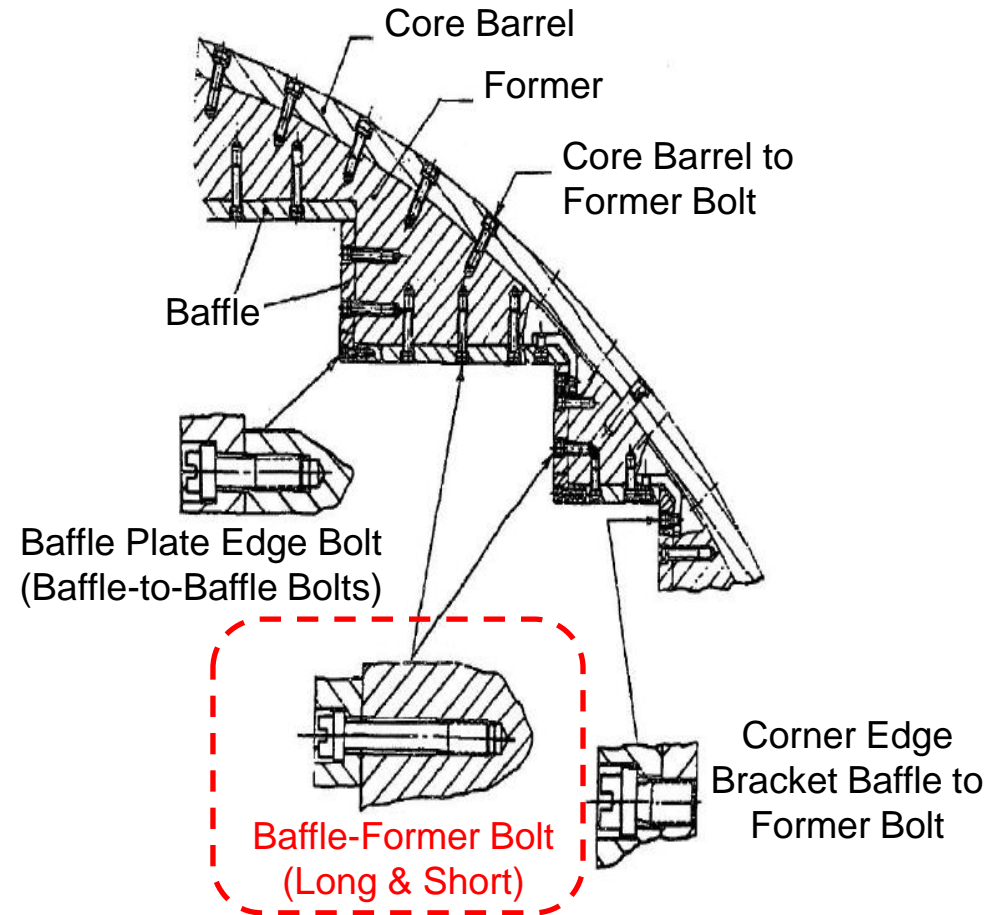
Baffle-Former Assembly



Source: ML15331A264

Baffle-Former Assembly Details

- Core barrel, baffle and former plates
 - Type 304 austenitic stainless steel material
- Baffle-Former Bolts (BFBs)
 - Attach the baffle plates to the former plates in the reactor lower internals assembly
 - Type 347 or Type 316 cold worked austenitic stainless steel material
 - Bolt head designs and shank lengths vary from plant-to-plant

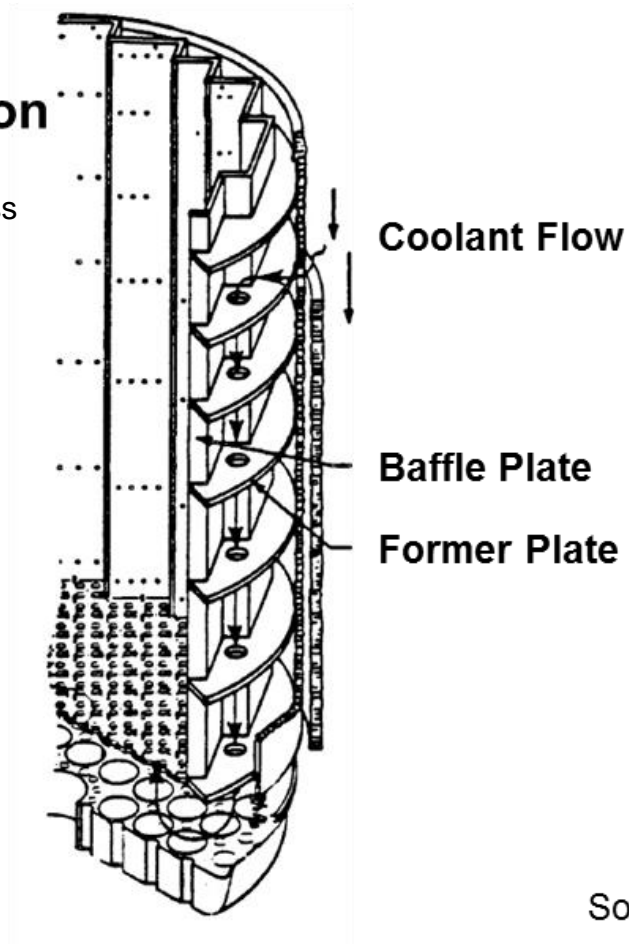


Source: ML15331A179

Coolant Flow Configurations

Downflow Configuration

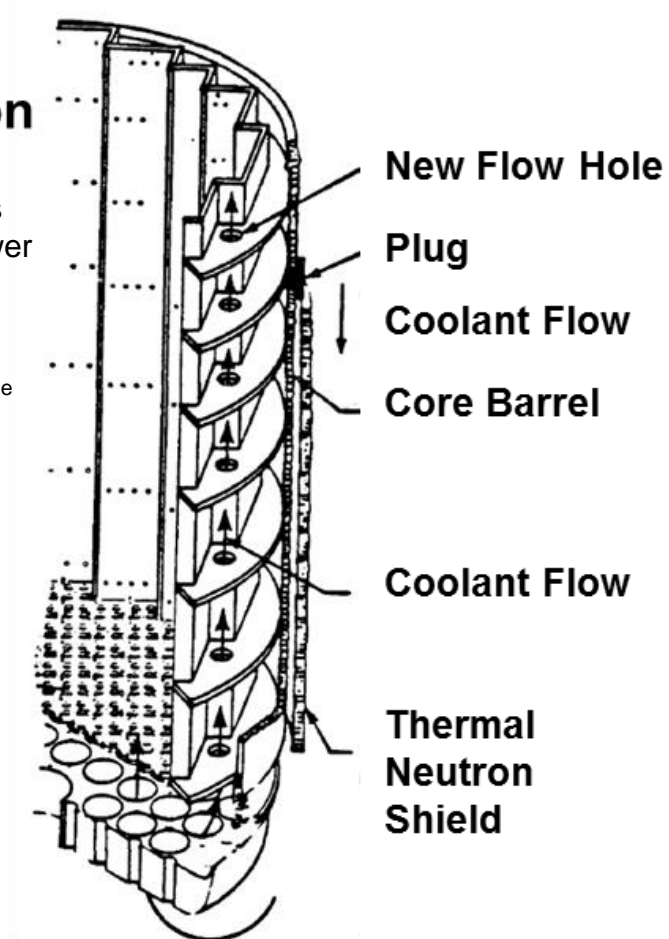
Large Differential Pressure (ΔP) Across the Baffle Plate -> greater BFB bolt loads



Upflow Configuration

Small Differential Pressure (ΔP) across the baffle plate -> lower BFB bolt load

*Figure shows modification made for Upflow Conversion



Source: ML073190376

Operating Experience Overview

Operating Experience

First UT baffle-former bolts (BFB) inspections in French PWR CP0 units and first cracks found

First degraded baffle-former bolts found in U.S.

DC Cook2 finds degraded bolts by visual inspection

Ginna performs first MRP-227 inspections

Indian Point 2, Salem 1, DCCook2 find degraded bolts (visual+UT)



WCAP-13266: BFB Program for the Westinghouse Owners Group - Plant Categorization

NRC Information Notice 98-11 on BFBs

MRP publishes assessment of French BFB OE (MRP-03)

MRP publishes Reactor Internals Inspection Guidelines (MRP-227)

NRC reviews & approves MRP-227

Westinghouse Technical Bulletin TB-12-5, related to the DC Cook OE

NSAL-16-1
AREVA CSB-16-02
Interim Guidance

Guidance

Per MRP-227-A, BFB UT exam is performed for WEC plants initially at 25-35EFPY and repeated every 10-years

Note: UT deployed as it becomes available and qualified for the various sites

Past Plant Operating Experience

EDF 1989-Present

Joint Owners Group Program 1998-2000

Westinghouse NSSS MRP-227-A Inspections

B&W NSSS and International Plant Results

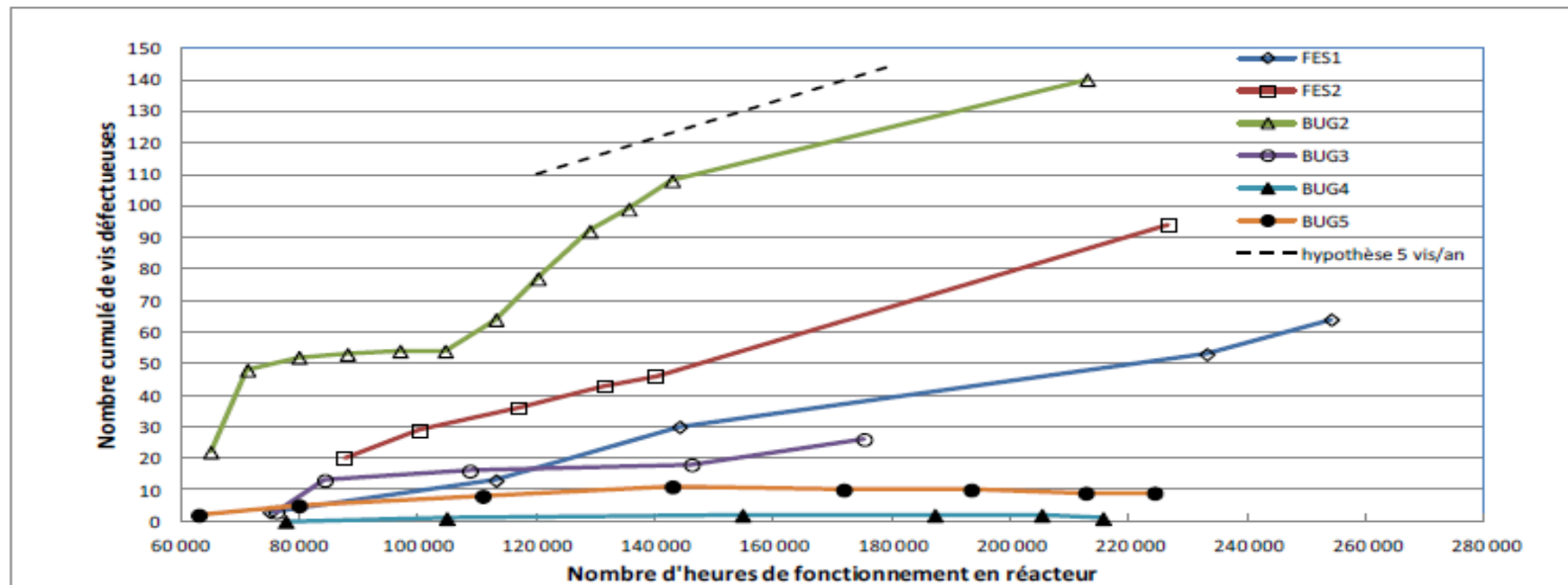
EDF Experience 1989-Present

- Baffle bolt failures reported - Limited to 'CP0' design
 - 3-loop (converted to upflow), with significant plant-to-plant variability (CPY design <5 indications over life of plant)
- EDF Periodic bolt replacement of failed original bolts, and periodic replacements included previously replaced bolts
 - Maintain sufficient number of “healthy bolts” to push next inspection to 10 years (based on observed failure rate of 5 bolts/year)



Overall BFB Timeline – CP0 Units

- X-axis: number of operating hours
 - Y-axis: cumulative number of bolts found 'failed'/'unconclusive'
 - ----- : evolution trend, assuming 5 failed bolts per year
- BUG2-FES2-FES1-BUG3: 4/6 CP0 units are 'affected'**
BUG5-BUG4: 2/6 CP0 units are 'unaffected'



Joint Owners Group Program (15-22 EFPY)

- Sponsored Inspections of four plants (1998-2000)
 - Ginna: 2-loop, Downflow, Type 347SS
 - 9% UT Indications (Of these, 14 were sent for metallurgical examination. Results showed no indications of cracking, so this 9% likely contains a number of false calls)
 - Partial replacement program
 - Point Beach Unit 2: 2-loop, Upflow (converted) , Type 347SS
 - 8% UT Indications
 - Partial replacement program
 - Farley Unit 1: 3-loop, Upflow (converted), Type 316SS
 - No UT Indications
 - Proactive replacement of minimum pattern
 - Farley Unit 2: 3-loop, Converted Upflow (downflow at time of inspection), Type 316SS
 - No UT Indications
 - Proactive replacement of minimum pattern
- Inspection results and metallurgical exams of bolts removed during this program led to conclusion that BFB degradation was not a concern for the original plant operating period and that this could be addressed by an aging management program for license renewal (MRP-227-A).

Westinghouse NSSS MRP-227-A BFB Inspections

through Sept. 2016 (excluding IP2, SAL1, DCCook2)

- Ginna: 2-Loop, Downflow, Type 347SS
 - 2nd Inspection (2011)(partial inspection of 123 original bolts and 56 replacement bolts): one additional UT Indication (Partial Replacement of 25 bolts)
- Point Beach Unit 1: 2-Loop, Upflow (converted), Type 347SS
 - 1st Inspection (2013): No UT Indications
- Point Beach Unit 2: 2-Loop, Upflow (converted), Type 347SS
 - 2nd Inspection (2014): 2% Additional UT Indications
- Prairie Island Unit 1: 2-Loop, Downflow, Type 347SS
 - 1st Inspection (2014): 6% UT Indications
- Prairie Island Unit 2: 2-Loop, Downflow, Type 347SS
 - 1st Inspection (2013): 10% UT Indications
- Surry Unit 1: 3-Loop, Downflow, Type 347SS
 - 1st Inspection (2010): <1% UT Indications
- Surry Unit 2: 3-Loop, Downflow, Type 347SS
 - 1st Inspection (2011): <1% UT Indications
- Robinson: 3-Loop, Downflow, Type 347SS
 - 1st Inspection (2013): <1% UT Indications
- Turkey Point Unit 3: 3-Loop, Downflow, Type 347SS
 - 1st Inspection (2015 - partial inspection of 305 bolts): No UT Indications
- North Anna Unit 1, 3-loop, Downflow, Type 347SS
 - 1st Inspection (2016): <1% UT indications

B&W NSSS and International Plant Results

- Crystal River Unit 3, Type 304SS (2005)
 - No relevant UT indications - UT performed due to visual indication from baffle-to-baffle bolts Oconee Unit 1, Type 304SS (2012)
 - No relevant UT indications - Four BFBs uninspectable due to large welds on locking bars
- Oconee Unit 2, Type 304SS (2013)
 - No relevant UT indications - One BFB uninspectable due to UT probe not seating properly
- Oconee Unit 3, Type 304SS (2014)
 - One BFB identified with crack-like indications - One BFB uninspectable due to UT probe not seating properly
- ANO Unit 1, Type 304SS (2016)
 - UT exams currently underway as of 11/14/2016
- Doel 1: 2-Loop Downflow, Type 316SS
 - 1st Inspection: No relevant UT indications (1991)
 - 2nd Inspection (2005) and 3rd Inspection (2015): 2% UT Indications (replaced 9 bolts in 2015)
- Doel 2: 2-Loop Downflow, Type 316SS
 - 1st Inspection (2006) and 2nd Inspection (2015): <1% UT Indications (replaced 7 bolts in 2015)
- Krsko: 2-Loop, Downflow (prior to inspection), Type 316SS
 - 1st Inspection: <1% UT Indications (2013)
- Tihange 1: 3-Loop, Upflow (converted), Type 316SS
 - 960 of 1088 bolts inspected in each of the following inspections
 - 1st Inspection: 4% UT Indications (1995)
 - 2nd Inspection: 3% UT Indications (2002)
 - Most recent Inspection: No relevant UT Indications (5 bolts either not inspectable or not interpretable) (2014)
- Ringhals 3: 3-Loop Downflow, Type 316SS
 - 1st and 2nd Inspections: <1% UT Indications/uninspectable (2000 and 2007)
 - 3rd Inspection: <1% UT Indications/uninspectable (2016)

Observations from Broader OE

- Excluding the OE at Cook Unit 2, Indian Point Unit 2, and Salem Unit 1 (discussed later in the presentation), the following observations can be made based on inspection OE gathered to date from international and domestic plants:
 - Bolts with UT indications tend to be randomly distributed
 - Distributions are consistent with expectations of IASCC failures and fluence effects
 - Quantity and distribution of bolts with indications bounded by historical generic safety assessment generated in mid-1990s (documented in report WCAP-15328)
 - Industry response to replacement of bolts with indications has been positive

Recent Plant Operating Experience

DC Cook 2 – fall 2010

Indian Point 2 – spring 2016

Salem 1 – spring 2016

DC Cook 2 – fall 2016

DC Cook Unit 2 (2010 / 22 EFPY) (4-Loop Downflow)

- Fuel failure in peripheral assembly attributed to wear against broken bolt head
- Bolt heads and lock bars found on lower core plate
- Visual inspections revealed 18 degraded bolts on 270° baffle plate in Rows 2-5
 - Additional bolts removed from plate with visual indications to define extent of localized degradation (approx. 40 bolts in single patch)
 - Additional test bolts removed from symmetrical locations to evaluate potential for degradation on other plates (all of these test bolts were found to be intact)
- No UT inspections performed in 2010 (at that time UT was not qualified or optimized for the Cook 2 bolt design)
- Degraded and test bolts replaced (total of 52 bolts and 2 open holes)
- Westinghouse issued Technical Bulletin TB-12-5
- 100% Visual VT-3 inspection conducted in 2012 with no additional indications

Indian Point Unit 2 (2016 / 31 EFPY) (4-Loop Downflow)

- Degraded bolts/lock bars noted visually prior to planned MRP-227 100% UT exams
- Markings on periphery of neighboring fuel assembly identified (no fuel failure).
- Inspections identified 227 BFB with visual or UT indications (includes 14 uninspectable)
- UT indications were clustered
 - Spanned various quadrants, mostly in former Rows D through G
 - Multiple groups of 10+ adjacent failures / At least one cluster of 50+ adjacent failures
- Observed failures exceed WCAP-17096-A engineering acceptance criteria
- Site-specific response
 - Performed Acceptable Bolting Pattern Analysis (ABPA)
 - Performed Replacement Bolting Pattern Analysis
 - Performed engineering evaluations supporting Unit 3 Extent of Condition Evaluation
 - Performed engineering evaluations supporting Unit 2 Assessment of Potential Safety Impacts
 - Performed baffle-former bolt removal and replacement
 - Quarantined select bolts for future testing

Salem Unit 1 (2016 / 28 EFPY) (4-Loop Downflow)

- Conducted visual exams every other refueling outage in response to DC Cook Unit 2 OE and TB-12-5; MRP-227 exams were not planned until 2017
- Degraded bolts/lock bars noted in visual exams followed by doing 100% UT exams
- Loose/protruding bolt heads resulted in fuel fretting and one fuel clad failure
- Inspections identified 182 BFB with visual degradation or UT indications (includes 18 uninspectable)
- UT indications were clustered
 - More concentrated (than Indian Point 2) to a few adjacent octants
 - Multiple groups of 10+ adjacent failures / At least one cluster of 50+ adjacent failures
- Observed failure pattern exceeds WCAP-17096-A engineering acceptance criteria
- Site-specific response
 - Performed Acceptable Bolting Pattern Analysis (ABPA)
 - Performed Replacement Bolting Pattern Analysis
 - Performed engineering evaluations supporting Unit 1 Justification for Past Operation
 - Performed engineering evaluations supporting Unit 2 Extent of Condition Evaluation
 - Performed baffle-former bolt removal and replacement
 - Quarantined select bolts for future testing

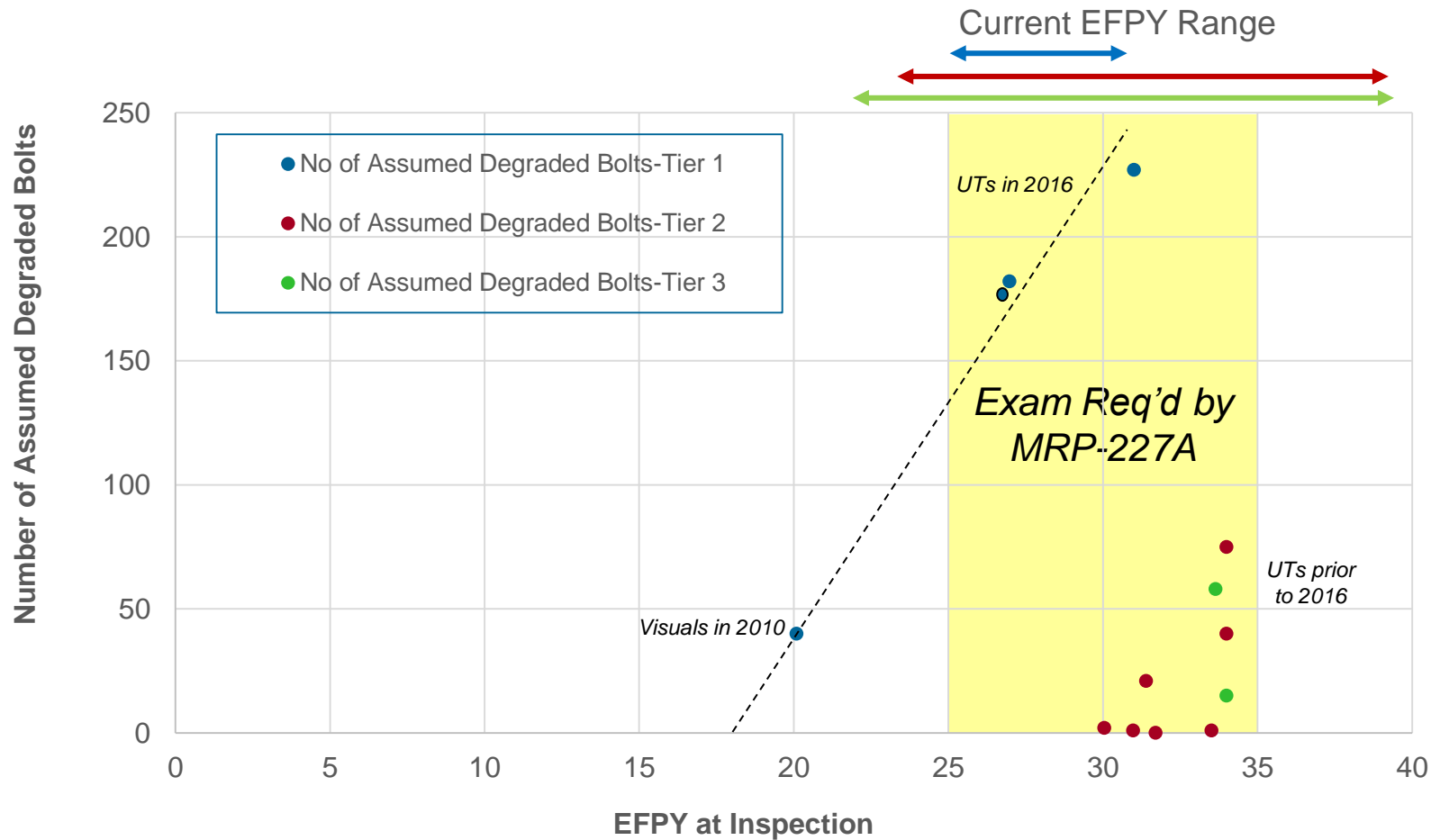
DC Cook Unit 2 (2016 / 28 EFPY) (4-Loop Downflow)

- Two (2) on-line fuel leaks identified during the last fuel cycle associated with two (2) empty bolt-holes from bolts that were not replaced in 2010 (suspected damaged by jetting through a vacant BFB hole)
- Inspections identified 179 BFB with visual degradation or UT indications (includes 9 that were not inspectable, and three (3) with visibly degraded lock-bar welds)
 - Includes 6 replacement BFBs from 2010 event that exhibit UT indications
 - Five (5) Baffle-Edge-Bolts on one seam appear visually failed
- UT indications were clustered
 - Spanned various quadrants
 - Multiple groups of 10+ adjacent failures / At least one cluster of 50+ adjacent failures
- Observed failure pattern exceeds WCAP-17096-A engineering acceptance criteria
- Site-specific response currently being implemented
 - Performed Acceptable Bolting Pattern Analysis (ABPA)
 - Performed Replacement Bolting Pattern Analysis
 - Performed engineering evaluations supporting Unit 2 Justification for Past Operation
 - Performed engineering evaluations supporting Unit 1 Extent of Condition Evaluation
 - Performing baffle-former bolt removal and replacement, expect to replace 200 bolts and plan to complete by 12/5/2016
 - Plan to quarantine select bolts for potential future testing

Conclusions from Recent OE

- These three plants share a common plant design configuration (4-loop downflow), bolt design, and bolt material
- Bolts with visual or UT indications tend to be clustered
- Distributions seem to indicate the presence of a mechanism causing adjacent bolts to become more susceptible to failure
- Assessing impact of new findings from DC Cook 2 exams:
 - Replacement 316 CW BFBs (6) from 2010 event with UT indications
 - Visually degraded edge bolts (5) on one panel, in the center of a large area/cluster of BFB failures

US Trends – BFB Focus Group Industry OE Database



Factors Influencing BFB Degradation

- Fluence, Stress, Material, and Time
 - Contribute to a condition conducive to IASCC crack initiation
 - Stress is influenced by plant design (loads), bolt design, stress relaxation, clustering (failure progression), and bolt replacement
- Plant design – number of loops, downflow/upflow
 - Impact the stresses that develop in the baffle-former bolts
- Bolt design
 - Bolts are either type 347 or cold-worked type 316 austenitic stainless steel material
 - While it is believed 316 has improved IASCC resistance based on our limited OE, insufficient direct comparative data exists at this point to make a definitive conclusion due to the introduction of additional variables (i.e. bolt design, plant operating parameters, etc.).
 - Type 347 bolts tend to have a sharper head to shank transition radius as compared to the type 316 designs
 - Type 347 bolts are generally shorter than the 316 bolts
 - Bolt length and head-to-shank transition radius (stress concentration) impact the average and peak stresses impacting IASCC and fatigue susceptibility and are believed to be more influential with respect to BFB degradation than material differences

Factors Influencing BFB Degradation (cont.)

- Stress relaxation
 - Occurs over a relatively short duration at high temperature and fluence
 - Reduces joint efficiency causing increased bolt loads
- Clustering of bolts
 - As failures occur, stresses redistribute into surrounding bolts
 - Increased stress can enhance IASCC susceptibility and fatigue / propagate existing cracks
- Bolt Replacement
 - Modifies how stress is distributed across bolts in the structure
 - May slow the process of degradation for nearby original bolts by tightening the structure and reducing load carried by original bolts

Explaining Failure Patterns

1. Randomly Distributed Failures

- Hypothesis: IASCC failure rate governed by stress, temperature, dose, time
- Key variables: Material, Plant Design, Bolt Design
- Simplified empirical representations and comparisons between plants can be used in this case: e.g. Weibull Distribution

2. Dose-Related

- Hypothesis: IASCC failure rate driven by temperature and stress from high dose rates which causes local acceleration
- Key variables: Fluence, Gamma Heating, Irradiation Creep, Void Swelling
- Good correlation with deterministic results from existing MRP aging model (IRRADSS Model): Predicted patterns similar to bolt failure experience in French CP0 plants

3. Clustered

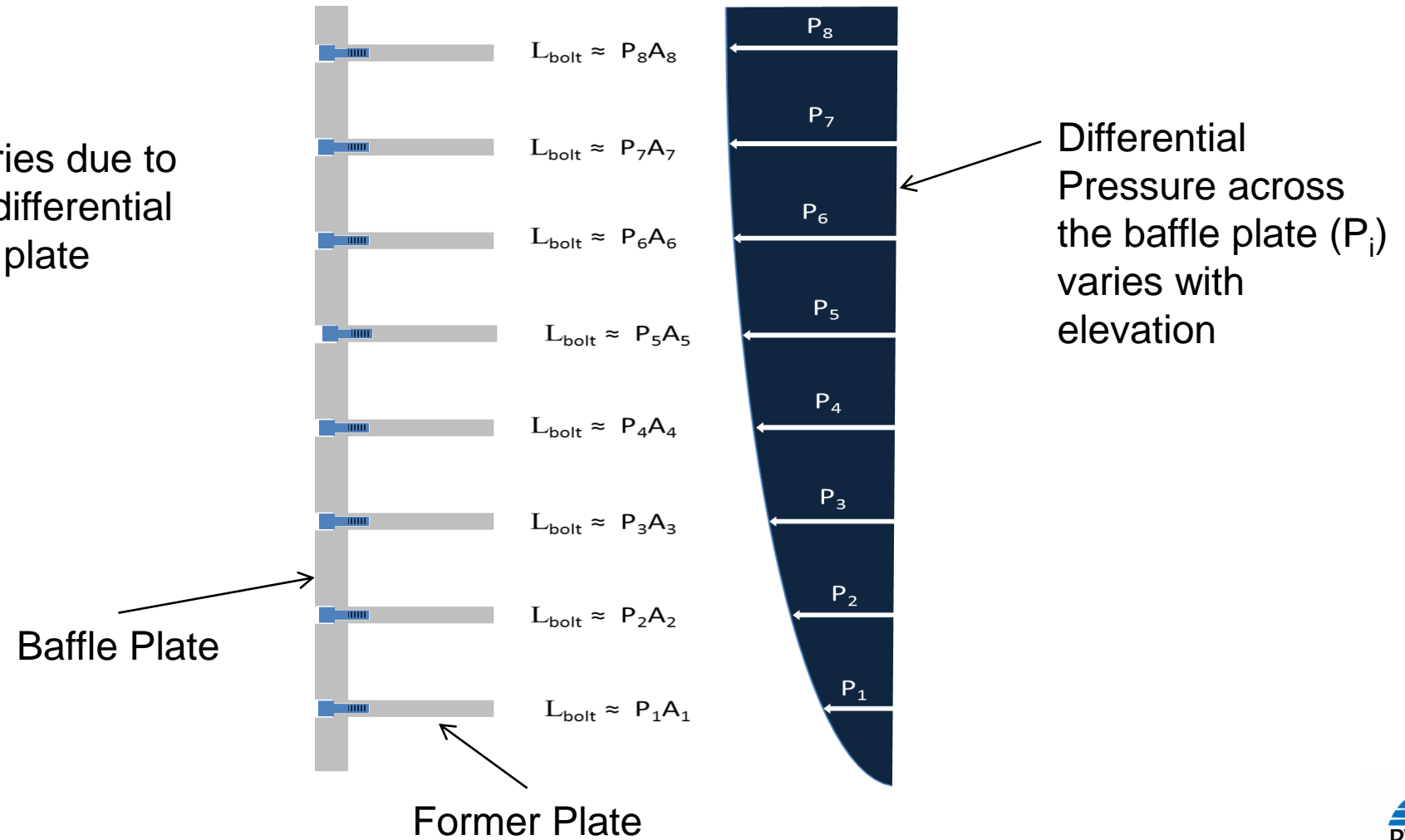
- Hypothesis: IASCC failure rate still affected by same parameters as random distribution but local stress increases around groups of adjacent failed bolts due to transfer of primary loads
 - Particular issue for downflow configuration plants due to high baffle plate ΔP
- Current modeling efforts are underway with the goal of replicating and predicting this failure pattern

Why Clustered Failures?

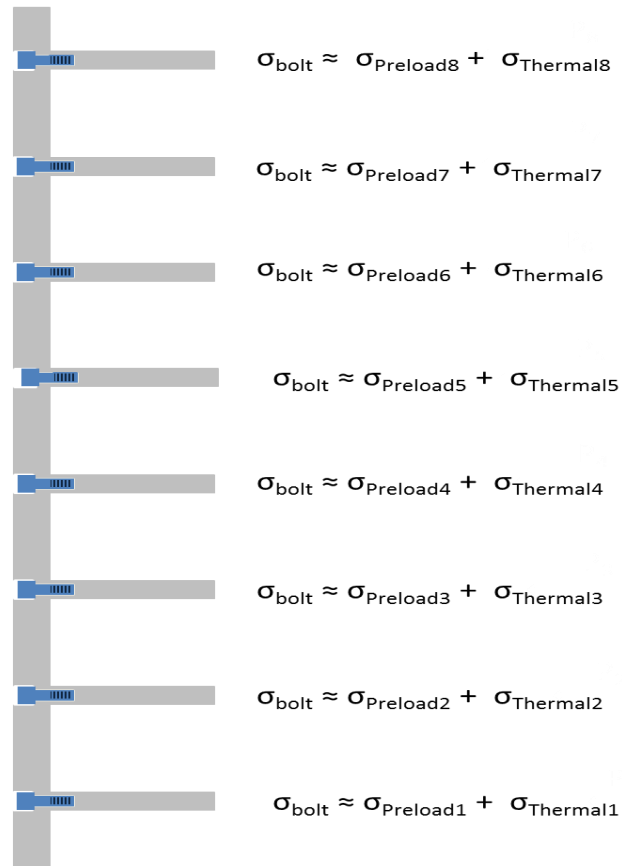
- **Answer 1:** Failures have a common cause that localizes the effects of IASCC or fatigue
 - Stress anomaly
 - Asymmetric fatigue
 - Local hot spot
 - Bolt source or installation sequence
- **Answer 2:** Failure propagates after initial random failures reach a critical level
 - Failures are random until adequate clusters of failed bolts form
 - Probability of failure in neighboring bolts increases with the increased load
 - Group of bolts “unzippers” as more and more adjacent bolts fail
- Possibly a combination of both of these answers

Vertical Stress Variation in Downflow Design

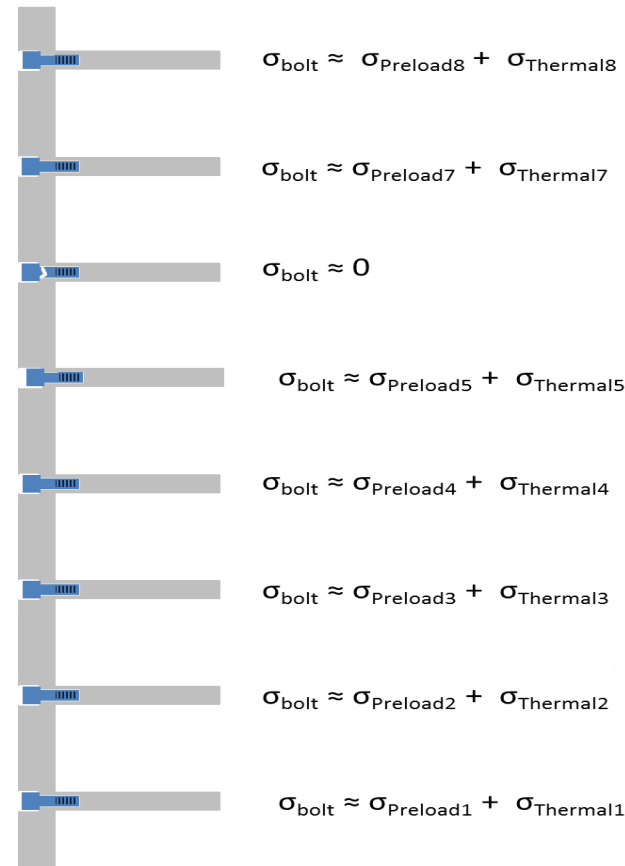
Bolt load (L_{bolt}) varies due to varying pressure differential across baffle plate



Stress Redistribution to Adjacent Bolts - Secondary



0 Failed Bolts



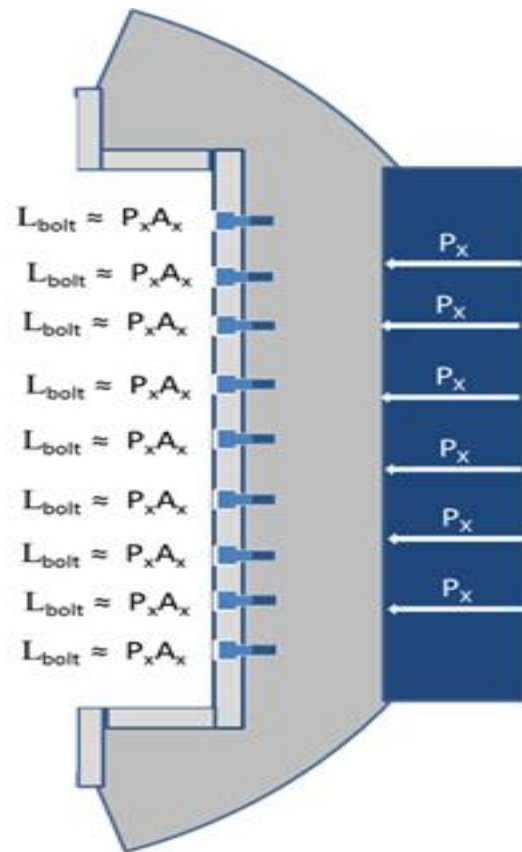
1 Failed Bolt

Secondary stresses predominant
in early life (bolt preload)

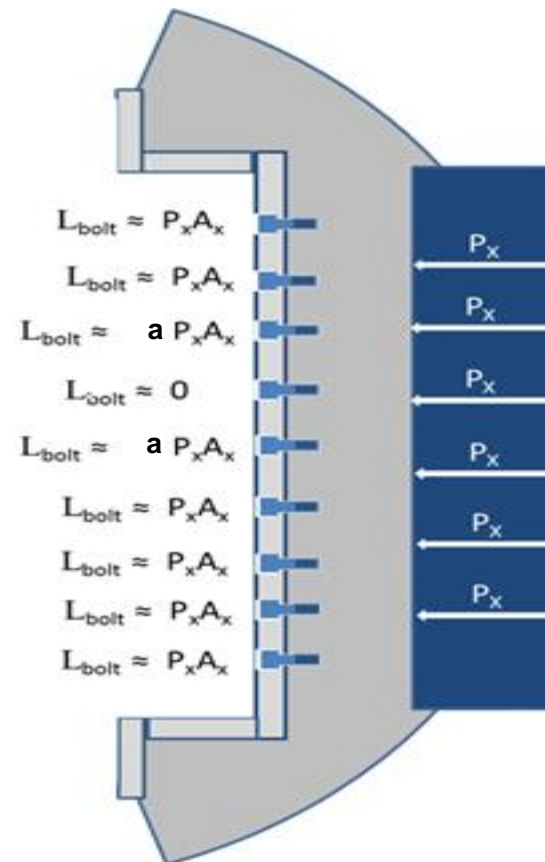
But do not redistribute with failure

Irradiation Induced Stress
Relaxation diminishes secondary
stresses over time

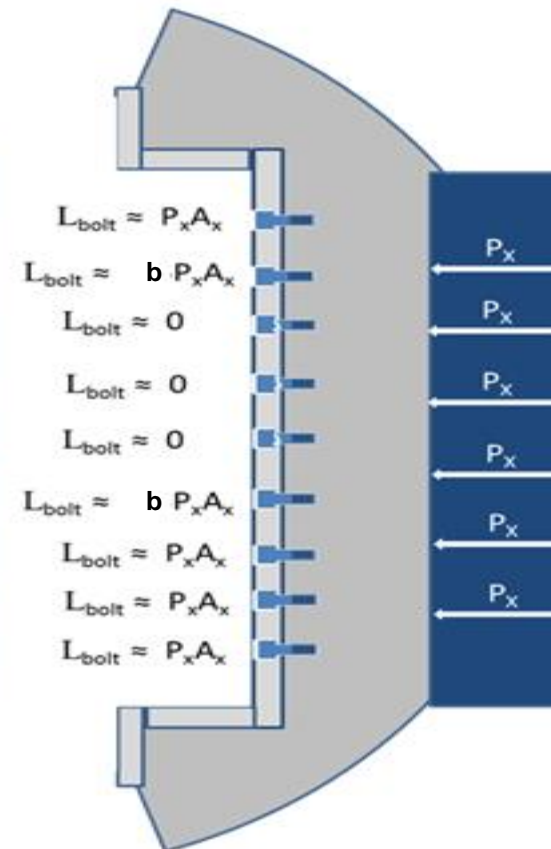
Stress Redistribution to Adjacent Bolts - Primary



0 Failed Bolts



1 Failed Bolt



3 Failed Bolts

Primary stresses dominate after irradiation stress relaxation occurs.

Stress redistributes as bolts fail.

First order approach shown in figure: $b > a > 1$

Consequences and Evaluation of BFB Degradation

- Degraded condition assumed for safety evaluations
 - It was assumed that all baffle-former bolts in a quadrant were degraded and a pinned constraint of baffle edges remained due to the presence of some edge bolts and/or overlapping plates
- Safety evaluations considered the following:
 - Impact on core bypass flow for non-LOCA and LOCA safety analysis
 - Control rod insertability
 - Fuel assembly grid crush and core coolability
- Conclusion was that plants would remain in a safe condition
 - Non-LOCA and LOCA safety analysis showed acceptable results when considering the increased bypass flow associated with this condition
 - Fuel assembly grid crush could occur in the peripheral fuel assemblies and to a much lesser degree in inboard fuel assemblies; however, this would result in a negligible impact on core coolability
 - Control rods would be able to fully insert to shut down the plant
 - Therefore, the ability to cool the core, maintain reactor shutdown, and remove decay heat in the long-term after a LOCA, would not be compromised by baffle-former bolt degradation

Consequences and Evaluation of BFB Degradation (cont'd.)

- Additional evaluations of BFB degradation included:
 - Baffle jetting
 - Loose baffle plates could result in opening up of baffle-to-baffle gaps or flow holes around broken bolts
 - Result would potentially be increased fuel rod vibration and wear
 - Monitoring of coolant activity will detect the presence of damaged fuel
 - Loose Parts
 - Heads of failed BFB generally remain trapped by the lock bar
 - Cracked lock bar welds and protruding bolt heads have been found in areas of large clusters of failed BFB
 - Loose bolt heads and lock bars can result in localized fretting of the fuel rod cladding
 - Monitoring of coolant activity will detect the presence of damaged fuel
 - Loose bolt heads will remain trapped by the adjacent fuel assembly
 - Lock bars can enter the reactor coolant systems but have been determined to have a negligible impact on safe operation

Industry Communication

- Tech Bulletin, TB-12-5, was issued in March 2012 after the Fall 2010 Cook Unit 2 visual findings of damaged baffle-former bolts
- Nuclear Safety Advisory Letter, NSAL-16-1, released on July 5
 - Determination of leading and affected plants was consistent between TB-12-5 and NSAL-16-1
 - Westinghouse 4-loop downflow plants are most susceptible
 - All Westinghouse designed NSSS plants with baffle-former bolts and CE designed plants with bolted core shrouds are potentially affected by this issue
 - The Westinghouse AP1000® plant design does not utilize baffle-former bolts and is not affected by this issue
- Affected plants broken down into 4 Tiers



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Intent of NSAL Recommendations

- Current working theory is that the cause of the failures is correlated more closely to key design features (previously discussed) rather than plant-specific operation or conditions
- Based on this, a tiered approach was chosen to rank plants based on how closely key design features matched design features of the plants that have experienced the OE
- The tiered approach also used past inspection data to inform a relative ranking between tiers and sub-tiers
- The NSAL Recommendations are intended to:
 - Promote early identification of failures (ideally before significant clustering has occurred) to retain safety margin
 - Progressively evaluate the extent of condition (this also helps to prove/disprove the working theory)
 - Enable lessons learned from initial inspections to be applied in developing future actions for plants that are perceived to be less susceptible

NSAL Recommendations

- **Tier 1a (4-loop downflow plants with Type 347 bolt design):**
 - Complete a UT volumetric inspection of the baffle-former bolts at the next scheduled refueling outage
 - In preparation for this inspection, the plant should consider developing an ABPA and be prepared to replace any baffle-former bolts with visible damage or UT indications
 - Additional mitigation strategies include upflow conversion and preemptive bolt replacements
- **Tier 1b (4-loop downflow plants with Type 316 bolt design):**
 - Complete a VT3 (visual) inspection of the baffle-former bolts at the next scheduled refueling outage
 - If any visual indications are found, it is recommended that the plant completes a UT volumetric inspection of the baffle-former bolts
 - If no visual indications are found, it is recommended that the plant completes a UT volumetric inspection of the baffle-former bolts prior to the completion of the second refueling outage after the issuance of this NSAL

NSAL Recommendations (cont'd.)

- **Tier 2a, 2b, and 2c (2- and 3-loop downflow plants):**
 - Plants that have previously completed UT inspections should review the inspection records to identify any indication of the onset of clustering before the next scheduled refueling outage
 - Clustering is defined as 3 or more adjacent bolts or a total number of failures in a single baffle plate > 40% of the total number of bolts on that baffle plate
 - Any indication of clustering should result in the consideration of an accelerated re-inspection schedule
- **Tier 3 (Converted upflow plants):**
 - 4-loop plants that have operated in a downflow configuration for more than 20 years should evaluate the need to perform a UT volumetric inspection of baffle-former bolts on an accelerated schedule
 - All other plants should follow the General Recommendations for all Tiers (see next slide)
- **Tier 4 (Designed upflow plants):**
 - Follow the General Recommendations for all Tiers (see next slide)

NSAL Recommendations (cont'd.)

- **General Recommendations for all Tiers:**

- If visually damaged baffle-former bolts or lock bars are detected, it is recommended that the fuel assemblies that were adjacent to the baffle in the previous cycle, and are scheduled for use in the next cycle, be inspected for fretting wear on the face that was adjacent to the baffle
- It is recommended that the plant continues to follow the current MRP-227 guidelines and implement any revisions to the MRP-227 recommendations

Acceptable Bolting Pattern Analysis (ABPA)

- Methodology based on PWROG report WCAP-15030-NP-A, “*Westinghouse Methodology for Evaluating the Acceptability of Baffle-Former-Barrel Bolting Distribution Under Faulted Load Conditions*,” February 1999.
- Acceptance criteria for MRP-227-A inspection of baffle-former bolts per WCAP-17096-NP-A, Rev. 2, “*Reactor Internals Acceptance Criteria Methodology and Data Requirements*,” August 2016.
- Bolting pattern is evaluated to satisfy normal, upset and faulted condition design qualification allowables from the ASME Section III and functional requirements.
- Bolting pattern is evaluated using 1/8th symmetric models of the baffle former assembly.
- Edge bolts are not credited in the demonstration for structural acceptance of the baffle-former assembly.
- Although the large percentage and clustering of BFB failures at the 4-loop downflow plants recently examined exceeded the acceptance criteria, there remained margin such that these findings did not trigger a substantial safety hazard status under 10CFR Part 21.

Westinghouse Replacement Bolts

- Replacement bolt design improvements to reduce impact of factors influencing bolt degradation
 - Cold Worked Type 316
 - Past operating experience using this material for baffle-former bolts and guide tube support pins has generally been positive. However, insufficient direct comparative data exists at this point to make a definitive conclusion
 - Semi-Parabolic head-to-shank transition fillet radius to reduce stress concentration and increase flexibility
 - Improved fatigue resistance
 - Reduced susceptibility to IASCC initiation
- Additional design improvements made for installation efficiency and ease of examination



BFB Focus Group Activities

Industry Response

- The Industry Baffle-Former Bolt Focus Group (BFB FG) was formed in May 2016 to support an integrated approach among industry organizations to address recent operating experience
 - AREVA
 - EPRI
 - PWROG
 - Utility Staff
 - Westinghouse
 - Others
- Six focus areas with key actions defined

Focus Area	Lead Organization
#1 – /Extent of Condition, Interim Guidance, Technical Interfacing with the NRC	MRP
#2 – Plant/Fleet Operating Experience Assessment	PWROG
#3 – Repair/Replacement	PWROG
#4 – Inspection/NDE	MRP
#5 – Irradiated Testing Support	MRP
#6 – Aging Management Assessment	MRP

Industry Response

Joint EPRI/PWROG BFB Focus Group established to determine how MRP-227 guidance will change as a result of recent OE

- *Focus Area #1: Cause and Extent of Condition, Interim Guidance*
 - Develop BFB OE database and verify data
 - Evaluate/trend BFB OE
 - Develop Interim Guidance
- *Focus Area #2: Plant and Fleet Operating Experience Assessment (PA-MS-1473) (PWROG Lead)*
 - Westinghouse to complete the 10CFR21 evaluation
 - Westinghouse to complete an NSAL; AREVA to produce a similar document for B&W plants (Customer Service Bulletin)
- *Focus Area #3: Repair and Replacement (PWROG Lead)*
 - Work with vendors to develop a contingency plan for tooling and bolt inventory for the upcoming outage seasons (Fall 2016 and Spring 2017)

Industry Response

- *Focus Area #4: Inspection / NDE*
 - Review bolt inspection protocols to see if lessons learned suggest modifications
 - Understand UT Probability of Detection as related to UT-acceptable bolts
- *Focus Area #5: Irradiated Testing Support*
 - Establish an integrated testing plan to build upon the Indian Point 2 root cause evaluation/analysis and further advance IASCC susceptibility knowledge
 - Evaluate the need to include Salem 1 and Ginna BFBs into an integrated testing program
- *Focus Area #6: Aging Management Assessment*
 - Review previous aging management assessments and compare to current OE experiences
 - Evaluate prediction models like the Weibull distribution in MRP-03 (which is based on French data)
 - **Long term functionality of MRP-227-A**
 - Has merged with Focus Area #1

Near Term Industry BFB FG Actions Completed

- Supported presentation to NSIAC on 5/23/2016
 - Westinghouse Technical Bulletin TB-12-5 remains valid
- Provided Industry Alert Letter from the PMMP Chairman to PWR site VPs on 6/1/2016
 - Expect that NEI 03-08 Interim Guidance will require the 4-loop plants identified in the Westinghouse TB-12-5 bulletin to perform UT inspections of all the BFBs or replace an acceptable pattern of bolts at their next outage.
 - Consideration should also be given to proceeding with procurement of replacement bolts prior to issuance of interim guidance due to potentially long manufacturing lead times.
- Westinghouse NSAL 16-1 issued 07/05/16 and revised 08/01/16
- AREVA CSB issued 07/14/16

Near Term Industry BFB FG Actions Completed

- Issued NEI 03-08 “Needed” Interim Guidance regarding BFB inspections for Tier 1 plants (7/25/2016) and for Tier 2 plants (9/29/2016) as identified in Westinghouse NSAL 16-1
- Assessed Fall 2016 and Spring 2017 outage seasons for developing a contingency plan for tooling and BFB material needs
 - Fall 2016: 3 planned MRP-227 UT inspections (1 of 3 is a Tier 1a plant) and 1 VT-3 inspection (Tier 1b plant)
 - Spring 2017: 2 planned MRP-227 UT inspections (both Tier 1a plants), 1 planned UT inspection (non MRP-227 but a Tier 1a plant), and 1 VT-3 inspection (Tier 1b plant)
- Initiated Hot Cell Post Irradiation Examinations of Indian Point 2 BFBs
 - Microscopic examinations have begun and are currently underway

Planned BFB FG Activities through Mid-2017

- Finalize BFB OE database by adding international data and UT inspection results from 2016-2017 exams in the US
- Continue with Hot Cell PIE work for IP2 and SAL1
- Explore providing additional NEI 03-08 Interim Guidance for the remainder of U.S. PWR fleet later in Fall 2016 or early 2017
- Establish fundamental understanding of BFB failure mechanism(s) and develop potential changes to MRP-227 inspection guidance as needed
 - Re-inspection frequency for UT exams
 - Allowance for proactive BFB replacement to manage aging



Together...Shaping the Future of Electricity



The Materials Committee is established to provide a forum for the identification and resolution of materials issues including their development, modification and implementation to enhance the safe, efficient operation of PWR plants.