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NUCLEAR REGULATORY COMMISSION

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PUBLIC MEETING

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BRIEFING ON CORE SHROUD ISSUES

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PUBLIC MEETING

U.S. Nuclear Regulatory Commission
One White Flint North
Rockville, Maryland

Wednesday, February 1, 1995

The Commission met in open session, pursuant to notice, at 2:00 p.m., Ivan Selin, Chairman, presiding.

COMMISSIONERS PRESENT:

IVAN SELIN, Chairman of the Commission
KENNETH C. ROGERS, Commissioner
E. GAIL de PLANQUE, Commissioner

STAFF SEATED AT THE COMMISSION TABLE:

KAREN CYR, General Counsel

JOHN C. HOYLE, Acting Secretary

JAMES TAYLOR, Executive Director for Operations

WILLIAM RUSSELL, Director, NRR

BRIAN SHERON, Director, Division of Engineering, NRR

ASHOK THADANI, Associate Director for Inspection and Technical Assessment, NRR

EDWIN HACKETT, Senior Materials Engineer, NRR

P R O C E E D I N G S

[2:00 p.m.]

CHAIRMAN SELIN: Good afternoon, ladies and gentlemen.

I'm pleased to welcome members of the staff to brief the Commission on the cracking of boiling water reactor core shrouds and on the more general question of aging of internals of boiling water reactors.

The Commission has the impression that once the staff became aware of these problems in 1993 that they and the industry have, in fact, worked together both smoothly and productive to assess the overall safety significance to bound the problem, to improve the inspection methodologies in order to detect the problem and to move quickly. Instead of hoping that the problem would go away, to move quickly with repair plans to limit the possibility of core shroud separation in case of certain design basis accidents or seismic events.

We're particularly interested in the discussion of the inspections conducted to date by licensees in accordance with our generic letter of last July.

Commissioner Rogers?

Mr. Taylor, would you proceed?

MR. TAYLOR: Good afternoon. With me at the table are Bill Russell, Brian Sheron, Ashok Thadani and Ed

Hackett, all from NRR.

Mr. Chairman, this will update the Commission on several papers that we've given the Commission, the last one in November of this past year, and we have of course more up to date and additional information from that briefing, particularly on the core shroud examinations and the work that's been going on. Brian Sheron will be the principal briefer.

Brian?

MR. SHERON: Thank you.

Could I have the first slide, please?

[Slide.]

MR. SHERON: This is just an outline of the topics which I'll touch on during the briefing.

Next slide, please.

[Slide.]

MR. SHERON: This is just to show you a configuration of the core shroud. You'll note that it sits inside the vessel between the -- or just inside the jet pumps which sit between the vessel wall and the shroud.

Just to refresh you on your memory on this, the core shroud basically is provided to direct the flow through the core, provide structural support for the core, lateral support for the core, proper control rod insertion geometry and provides a refloodable volume following a loss of

coolant accident.

Next slide, please.

[Slide.]

MR. SHERON: This shows again the core shroud. What's of note here is the location of the welds which is of primary concern. This model here, which is a Brunswick shroud, will help you visualize. This is about 1/20th scale actually. The shroud is about 20 feet high. This shows you where the welds are, both the vertical welds as well as the horizontal ones. They're numbered. These are not the same numbering for every shroud, but they're fairly consistent and it's usually at the top, starts at H1 and works its way down.

What you see here, these narrow ones are rings which sit in and that's where the top guide and also the core plate would sit on. You'll see that further in some other drawings. You'll note that the jet pumps sit right on the outside of this and are actually attached to the shroud up at the top portion there.

Next slide, please.

[Slide.]

MR. SHERON: Shrouds are made of stainless steel, either 304 or the low carbon stainless steel. As I said before, the height is around 20 feet high. Diameters range from 14 to 17 feet. The walls, which are normally about one

and a half to two inches thick, are actually that thick because of concerns for stiffness when they transport it and so forth. If one actually had to look at what is the required thickness to meet the structural demands when it's in operation, my understanding is that you could actually have a shroud that's half an inch thick. So, there is a lot of margin in the structural design of the shrouds.

As I said before, it's constructed of welded plates which are these, as you can see, which are rolled and then welded. The rings here can either be welded plates where they're actually cut from a rolled plate and then welded together into a ring or they can be forged. That's of interest when one is looking is stress corrosion cracking and the causes of it. You get stresses in this mostly from the residual stresses from the welds. When you weld something you're heating it up, as it cools it builds up residual stresses in the vicinity of the weld area. It's the weld area in what we call these heat affected zones that is particularly susceptible to the stress corrosion cracking.

Next slide, please.

[Slide.]

MR. SHERON: As I said, this is a model of the Brunswick shroud. Brunswick was actually the first U.S. plant that saw cracking in the shroud. It was discovered

during a routine examine as recommended by GE. It occurred at H3, which on this you can see is right up here by the top ring. The extent was 360 degrees around the circumference and the maximum depth was 1.7 inches out of a two inch thick shroud. So, you can see it was fairly deep.

Similar cracking in the core plate support ring, which is down -- on this one it's H6. I believe it was H5 in Dresden and Quad Cities. This was also seen at -- I'm sorry, Dresden 3 and Quad 1, which we found last spring. I'll be discussing this further.

Next slide, please.

[Slide.]

MR. SHERON: On this slide, this actually shows you where the cracking was seen at Dresden and Quad cities. This shows the actual location of the crack which is on the ring which was right down here. You can see these cracks many times grew from the outside in, although we have seen in other instances where we saw cracking on both sides. So, it's not preferential to one side.

Next slide, please.

[Slide.]

MR. SHERON: The real question obviously is what is the safety significance of all this. Well, first off, the fact that it's cracked is not of immediate concern. What's really of concern is if it's cracked all the way

through and can be detached, you might say, so that these rings can be separated. Under normal conditions, if you have a crack in the upper elevation, what will happen is that the flow -- remember on top of this whole thing there's a dome with steam dryers and everything and the flow will actually lift. There's enough force that it will actually life the upper portion slightly.

What happened, since the pressure on the outside is higher than the pressure on the inside, remember the flow is coming in, going down through the jet pumps and up through the core so there's a pressure drop, you will get flow going in, directed in through any cracks that exist. What you would see is a power to flow mismatch and the operators would be able to detect it. If you did have cracks in these lower elevations, however, there's not enough force to lift this thing up. So, what happens is you're not going to see any flow going in and you may not be able to really see it or anything.

The accidents that we worry about with this, there's about three that really concern us, the main steam line break, an earthquake or a recirculation line break. With the steam line break, as you know, which the break will be at the top, so the forces, the flow, et cetera, will be trying to go this way through the core. What you're worried about is that if it does lift this -- if you can see on the

top here, there's a thing called the top guide where the control rods are held in place. If that lifts too far, what happens is you lose the lateral support of the fuel assemblies and so forth and you may not be able to insert the control rods. You'll get misalignment. So, the concern there is if it lifts too much during a steam line break and the rod is trying to go in, they may not be able to go in.

Earthquake, it's the same thing. If you shake this and it's broken here, if it can laterally displace, again you'll have a misalignment problem and the rods may not be able to go in.

With the recirculation line break, if you recall the recirculation line comes in low. The flow is directed up through pipes, in through the jet pumps, down and then through the core and up. What will happen is you will blow down through the core, so the forces are going to be going around the vessel, up and out through the break on the recirculation line and you get an asymmetric force on the core shroud. Okay. So, the force on one side is going to be higher than the other. If it's enough, there can be a tendency if this is cracked through at a lower elevation you will tip it over and maybe even laterally displace it. What happens is once the blow down is done, if this thing doesn't come back down in its original place, there's going to be a gap down here. Then when the ECC system comes on and tries

to reflood the core, what happens is it will only flood up to the point where there's still a gap and then the water is just going to flow out and go out the break.

So, as I said, this is required for the refloodable volume. So, if there's no crack here, you can flood this up and you cover the core and everything is okay. If it's cracked low and it's displaced, you can't reflood the core and you just have to rely on the core sprays, which may not be acceptable for some of the plants.

Next slide, please.

[Slide.]

MR. SHERON: This is just to show you schematically where things have to be flooded up to. This shows the flow paths in relationship to the core shroud. You'll see that you can flood during a LOCA in a recirc line up to the top of the jet pumps. After that, the water will just run down the jet pumps and out through the break. Okay. So you normally will flood these up to two-thirds core height and the steaming from the water that's boiling in the core, coupled with the spray, will keep the core cool.

Next slide, please.

[Slide.]

CHAIRMAN SELIN: I'm sorry. This is assuming that you have scrammed or you haven't scrammed?

MR. SHERON: Yes. Normally though, even if you -- once you blow the thing down and you void the core during the blow down, actually the reactor will shut down. But you worry about when you reflood whether you get any kind of criticality again.

Regulatory actions that have been taken to date. Well, when we saw the cracking at Brunswick, an Information Notice 93-79 was issued. Similarly, when we saw the cracking at Dresden 1 and Quad Cities 3, Information Notice 94-42 was issued, as well as a supplement to it. Then, as I'm sure you're aware, on July 25th of last year, we issued Generic Letter 94-03. This, in essence, required the industry or the BWR owners, I should say, to inspect and repair their core shrouds at the next refueling outage. They should provide -- and most importantly, this was the most important part, was provide a safety assessment as to why they believed their plants could continue to operate until they performed that inspection and then to provide us with their inspection and repair plans 30 days prior to the outage.

Next slide, please.

[Slide.]

MR. SHERON: Now, while we did all this, the industry was not sitting on their hands either. GE issued some service information letters with regard to the shroud

cracking that had been seen and recommendations, et cetera, for inspection. The owners formed what they called BWR vessel and internals project, which is a special committee. It is made up of senior vice presidents from the utilities, so it has a very high level of visibility within the industry. It is also, besides the main committee, it is compose of five subcommittees. There's an Integration Subcommittee, an Inspection Subcommittee, Assessment Subcommittee, Repair Subcommittee and a Mitigation Subcommittee. You can see that they have three of these subcommittees, the Inspection, Assessment and Repair Subcommittees, have all submitted topical reports so far. So, they have not been just giving us lip service, they've actually, I think, done a very credible job.

The inspection topical report gave guidance on doing inspections. The assessment topical report, which was actually the same as the inspection, gave guidance on how to do a structural analysis, and the repair topical gave guidance on the basically guidelines for designing a repair.

Next slide, please.

[Slide.]

MR. SHERON: Now, where are we today with all this? First, we've established what the key -- I mean this thing is all being caused by intergranular stress corrosion cracking of the metal near the welds. One thing we did is

we have established what the key factors are relative to where are these plants susceptible to this kind of cracking. We have met with EPRI and a BWR Vessel Internals Project Group to discuss the scope of core shroud inspections. This was an important part. There was a disagreement with the industry. Their initial proposal was to only inspect what I call minimum metal. In other words, they would go in and inspect and if they could demonstrate that there was sufficient ligaments in locations, say, I think a minimum like three inches in every quadrant, that would be sufficient to meet the requirements of the ASME code and therefore they would not inspect anymore at that weld.

We were not really in agreement with this. We felt that because of the significance of it that a utility should really go in and do a full inspection, 100 percent of all accessible welds in order to best characterize really the extent of the cracking and degree of the problem.

The other thing with regard to the inspections I would mention is that it was interesting that when they actually got in and did inspections, they ran into a myriad of problems, nothing runs smoothly. They have a device by GE called a tracking scanner which I believe sits and runs around here on top of the shroud. What was happening, it was getting jammed up and not working properly. There were some situations where they went in one plant, didn't even

have a shroud that was round. Okay. It was out of round. Another one, they found out that the gap between the shroud and the vessel was too small to fit this thing and it was jamming up in there. So, there are a number of problems which really affected the ability to do 100 percent accessible inspections on the first plants that really went in and did this.

The problem, really what that manifests itself in is that when they do it and they run into a problem, it affects their critical path. They're in an outage and therefore it was very painful if they had to continue to stay down while they did the inspection. So, there was always an incentive if they couldn't do the full 100 percent accessible weld, they would want to do only what was minimally necessary in order to get back on-line.

So, I think we've resolved that. We've had some meetings with EPRI down at the NDE Center in Charlotte and my understanding is that I think we've reached agreement with the industry on the scope of these inspections.

We are continuing our analysis of the inspection results from each of these plants as they come down and go in and do the inspection, trying to understand what they've seen, trying to again look at the correlation with regard to the susceptibility factors. We are also reviewing the assessments for the repair acceptability and I'll get to

that in a minute. Some of these plants are putting repairs in. We have completed our review of Generic Letter 94-03 responses.

I'll tell you right now that basically we found all of the responses acceptable in terms of the justification for operating until the scheduled outage that they plan to come down and do the inspection. There were several plants in the higher susceptibility category, which I'll also talk about, which we had a number of questions about their plans and their justification. On several occasions we brought them in for a day long meeting, I believe Pilgrim came in and Dresden 2 and Quad 2 came in, in which they gave us much more extensive presentations, but ultimately we were satisfied that they had a justification, proper justification for continuing the operation.

COMMISSIONER de PLANQUE: And you're now satisfied that the scope of the inspection program is adequate?

MR. SHERON: Yes, so far.

COMMISSIONER de PLANQUE: Okay.

MR. SHERON: With regard to Generic Letter 94-03, let me just go through some of the technical bases, why we felt it was acceptable to continue operating until the next inspection. These are more generic reasons. One is that despite the fact we have seen cracking, we have not seen any 360 degree through-wall cracking so far. No plants have

seen that and there may be a reason for that. That is that if you go back and look at those diagrams at the welds, what you will see is what we think is driving these cracks is the residual stresses from the welding. Once the crack proceeds past the heat affected zone, you run out of residual stress and that there's nothing left to drive the crack. So, they may self-arrest, but we don't know that for sure. But that may be the reason why we're not seeing anything through-wall.

We have not seen any symptoms of power to flow mismatch in any plants which would indicate even that even if a plant had not shut down and done an inspection that they were not experiencing any 360 cracks, at least in the upper portions. As I said before, in order for these things to hold together, you just need a very small ligament in the various quadrants. So, you can have like a ligament in only three quadrants or even in two. It was just a small distance, maybe three or four inches. That would be sufficient to hold this whole thing together.

The ASME code margins are satisfied based on all the inspections that we've seen, even the ones that have seen some cracking. Dresden and Quad Cities, for example, which, as you know, they came in and justified continuing to operate for 15 months even though they did have some cracking. It wasn't through-wall. The reason was because

they did a stress analysis and showed that the ASME code margins were still satisfied, even assuming crack growth rates over the cycle that they would propose to run the plant.

Also, there's a low frequency of the initiating event. As I said before, these things -- the real concern is when you have either a steam line break or a recirculation line break. These are relatively low frequency events. We've never seen one or anything. So, the likelihood of getting one of these in the period before they inspect is fairly low. The reason too is it's a short period of operation. Those plants will be inspecting within months of when they got the letter.

There are a number of plant-specific factors which we also took into consideration for the higher susceptibility plants. These have to do with things like water chemistry, the low radial stresses on the lower weld, for example, at a non-jet pump plant.

COMMISSIONER ROGERS: Just before you leave that.

MR. SHERON: Yes, sir.

COMMISSIONER ROGERS: Do you recall what those ASME code margins are, how they work?

MR. SHERON: Yes. We actually anticipated that question. My understanding is they are for accidents. They're 1.4 times the allowable stresses and they are 2.77

times allowable stresses for normal operation.

COMMISSIONER ROGERS: And how well are they satisfied here?

MR. SHERON: Ed, you looked at that.

MR. HACKETT: They're satisfied by quite a degree. As Brian said, 90 percent through-wall is almost what you could satisfy here. So, that means on the shroud you're talking something on the order of a tenth of an inch remaining metal that could satisfy these margins.

COMMISSIONER ROGERS: Thank you.

MR. SHERON: Then when we looked at Dresden and Quad Cities, for example, what we did is when we looked at how much longer they could operate before they would come down again to inspect, we used conservative crack growth rates. We assumed that these cracks would grow at that maximum rate and still maintain the ASME code margins.

DR. THADANI: That was for 15 additional months of operation.

COMMISSIONER ROGERS: And that ligament, how big is that that's required?

MR. SHERON: I'm sorry?

COMMISSIONER ROGERS: How large is the ligament required for adequate structural integrity?

MR. HACKETT: That would be what we were referring to just then as the tenth of an inch, for instance.

COMMISSIONER ROGERS: Oh, okay, just that. Okay. All right.

MR. HACKETT: It comes down to the fact that the steel is that forgiving a material.

COMMISSIONER ROGERS: I just viewed this as some kind of a bridging of cracks, but it's just residual material that's left.

MR. HACKETT: That would be a ligament left on the inside or the outside of the wall.

COMMISSIONER ROGERS: Fine. Fine. Thank you.

MR. SHERON: Could I have the next slide, please?

[Slide.]

MR. SHERON: Let me just talk quickly on the susceptibility criteria for stress corrosion cracking. These are the five elements which seem to have affected the greatest operational time. This is at power. Reactor water chemistry, in essence the conductivity of the water. As I said before, the carbon content of the material, high carbon being more susceptible than a low carbon content steel. Shroud fabrication methods, as I said, some plants, these rings right here are made from rolled plate and then cut and welded together into segments. In others, they're forged. When you have a rolled plate and you cut it, you leave basically an end grain here which is exposed then to the coolant. That seems to be more susceptible than the forged

rings. So, a plant that has a forged ring is less susceptible.

Then, as I said before, the weld stresses. Again, the residual stresses seem to be what's driving these cracks once they initiate.

COMMISSIONER ROGERS: Just on the water chemistry. What are the factors there that are most important? I seem to remember some time ago GE considering addition of zinc for some purposes, I can't remember what it was, probably to reduce crude or something, reduce radioactive background. But I don't remember what it was. But ten years ago or so there was a flurry of activity to consider the addition of zinc, small quantities of zinc. Has anybody looked at the relevance of that to this phenomena?

MR. HACKETT: They are looking at those as mitigation methods. Zinc would act as a sacrificial anode, would be the appropriate term electrochemically. What they're looking at now is potentially noble metal coatings and possibly the additions of catalysts to the reactor coolant water. The idea there would be to reduce what's called the electrochemical potential, which is the driving force for stress corrosion. So, that's some of the methods that they have under consideration for mitigation.

COMMISSIONER ROGERS: But these are really microscopic, very tiny.

MR. RUSSELL: Very small.

COMMISSIONER ROGERS: Yes.

MR. RUSSELL: They're also looking at hydrogen water chemistry to potentially assist as well. That has the downside of increased radiation source term. So, that's one that's being looked at carefully on a plant by plant basis.

COMMISSIONER ROGERS: Well, the question I had in mind was whether there's any connection between any specifics of the water chemistry programs of these reactors that are showing this and any of the proposed -- well, any of the considered treatments, water treatments that have been either used or not used over the last 20 years or so.

MR. HACKETT: Really, what it comes down to is to a large degree it's cleanliness. The cleaner the water or the lower the ionic content, the less the conductivity and hence the less the driving force for the reaction. So, over the years they've tried to increase the cleanliness of the water primarily and the EPRI has published guidelines on cleanliness of the BWR water.

Then the VIP, as Brian alluded to earlier, has one subcommittee on mitigation that's studying some of these advanced methods. The only one that's employed at the moment is hydrogen water chemistry which was used very effectively for the recirc piping and there's good arguments to be made that it would be very effective for the lower

internals but less effective as you go up through the core.

COMMISSIONER ROGERS: Yes. My understanding is you have some questions about that, how effective that is over the life of the plant --

MR. HACKETT: That's right.

COMMISSIONER ROGERS: -- when it might be effective and when it might, in fact, be sort of a negative factor.

MR. RUSSELL: We've discussed it in the context of mitigation. I think it's also important to recognize that the history of prior water chemistry, particularly if there had been any excursions, contaminants going in, could be quite significant. That's one of the things that was looked at. Generally, some of the older reactors did not have the same water chemistry treatment early on and have had, even in some cases, some chloride intrusion, so that those may be making it more susceptible than others.

COMMISSIONER ROGERS: But so far you haven't been able to connect any of that with this particular phenomenon. Is that right?

MR. HACKETT: There is a correlation between -- you raised an interesting point. What we'd like to have is a measure of the electrochemical potential for all these plants. We don't have that necessarily as a function of core height. What we do have is the conductivity. Actually

there is a very good correlation with the industry tabulated the average over the first five cycles for many of these plants, their average conductivity. We have found that when that average is high we do see a relatively high incidence of cracking. There's been a very strong correlation there.

COMMISSIONER ROGERS: Thank you.

MR. SHERON: Could I have the next slide, please?

[Slide.]

MR. SHERON: Picking up on what Ed said on the susceptibility rankings, you will see that water chemistry is one of the key factors here. We've actually categorized the plants, the fleet of BWRs, into three categories with regard to susceptibility to experiencing the stress corrosion cracking. You will see that category A, which is the least susceptible plants, there are eight units that we feel are in that category. The criteria there are that they've been on-line less than eight years. They've had good initial water chemistry and they have low carbon steel in their shrouds.

The middle category, Category B, there are six units there. For these plants they would have been on-line more than eight years. They've had good to moderate initial water chemistry and again low carbon steel.

Then, where the majority of the units fall, 22, Category C, these would have more than six on-line years for

BWRs with shrouds fabricated from the regular 304 stainless and eight years for those constructed using the low carbon. They would have moderate to poor water chemistry.

Could I have the next slide, please?

[Slide.]

MR. SHERON: Now, of the 22 plants in Category C, we looked at those a little bit harder. What we concluded was that of the 22, 11 really had the potential for significant cracking. We felt that when we looked at the conditions at these plants, we felt that they bounded all the other BWRs.

What I'm showing here is these 11 plants. They're basically ranked in order of their susceptibility. The other two columns show either if they've inspected or plan to inspect and also whether they have installed a repair yet or when they plan to install a repair.

The three plants that have put the repairs in so far are Fitzpatrick. Actually, they're doing it right now as we talk, I think. Oyster Creek has completed their repair. Brunswick 1 and 2 completed a repair but it was not what I will talk to you about, which is the tie rod design. It was these clamps because they only saw cracking at the H2, H3 area here and they put these small clamps on. These are not the kind of repairs that were done at Hatch or at Oyster Creek, but I've got some pictures of those repairs a

little bit later.

COMMISSIONER ROGERS: Excuse me. On that table, those ones at the top of the list that the repairs have already been done, would they have been at the top of the list if they --

MR. SHERON: I'm sorry.

MR. RUSSELL: That's when they're scheduled.

MR. SHERON: They're not done yet.

COMMISSIONER ROGERS: The ones that are completed are the ones at the bottom.

COMMISSIONER ROGERS: Oh, yes, they're '95.

MR. RUSSELL: This is basically a summary of their commitments to us in response to the generic letter.

COMMISSIONER ROGERS: I see. Okay. All right. In other words, the question is really whether this susceptibility list, in fact, tracks the development of these, that those that are most susceptible are, in fact, showing the cracking. Is that --

MR. SHERON: Well, we don't know. For example, Pilgrim has not inspected. So, we don't --

COMMISSIONER ROGERS: Which ones have actually shown cracks?

MR. SHERON: Well, the ones that show the inspection completed, the completed inspections which would be Dresden 3, Quad 1. Fitzpatrick I do not --

Did they inspect, Ed?

MR. HACKETT: Fitzpatrick did a partial inspection and didn't find much to report in the way of cracking.

MR. SHERON: And Oyster Creek did an inspection. They were actually doing very well until they reached the last weld, which was H4, right here. They found a crack from both the inside and the outside on a butt weld. It was never in any of these rings. They got around and they saw -- I think it was -- how much on one side was it and then 55 degrees on the other.

MR. HACKETT: About 120 on one side.

MR. SHERON: And they said, "To heck with it," and they said, "We're going to do a preemptive repair."

And then Hatch went in and they did a preemptive repair which several of us went down and observed while they were installing it this fall.

Next slide, please.

[Slide.]

MR. SHERON: This slide basically summarizes the overall inspection results to date. 13 of 22 Category C plants have completed their inspections. We've seen 360 degree circumferential cracking in four units. If you recall, these are Brunswick, Dresden 1, Quad Cities 3 and Oyster Creek, if you want to count what they had seen pretty much as a 360 crack. The cracks were primarily found in the

core shroud rings. Again, these are the rings here right around H2, H3 and down on this one about H6A and B, although, as I said before, Oyster Creek saw extensive cracking at H4 which is a butt weld. It is not an end grain on a ring.

The required structural margins, the ASME code were satisfied for all the identified cracks. In other words, no one was cracked to an unacceptable amount in the sense that we think all of them, even if they were to continue operating, would have still satisfied the ASME code.

Two Category B plants have been inspected. These were Susquehanna and LaSalle. There was no cracking identified in those plants.

One Category A plant actually did an inspection, Fermi 2, and again they saw no cracking.

Most licensees for the Category B and C plants should have their inspections or repairs completed by this coming fall.

[Slide.]

MR. SHERON: The next slide is merely a bar graph showing the cumulative number of plants that will have inspected or repaired by the spring of '96. You will see that by spring of '96 all the plants will have completed. I hope your viewgraph shows the distinction here. The

Category B is the short one and the Category C is the longer one. I think the Xerox didn't do too good a job here.

Next slide, please.

[Slide.]

MR. SHERON: Let me talk a little bit about the repairs that are being proposed. First off, if a licensee goes in and does an inspection, they have sort of two options if they see cracking. One is they could follow the course like Commonwealth Edison did on Dresden 3 and Quad Cities 1 and evaluate analytically the acceptability of leaving the shroud in place with the cracks by demonstrating that over the next operating cycle or however long they plan to operate it, assuming conservative things like initial crack depth, crack growth rate, that they would still satisfy the ASME margins at the end of that operating cycle. That's what led to the staff allowing those plants to go on for another 15 months.

The other thing they could do is install a repair option, which I'll talk about in a second. What we're finding is that economic factors really come into play here. The reason is that an inspection of these welds is not a cheap thing to do. It can run anywhere from half-a-million to a million dollars and if they run into problems during the inspection, if a machine breaks, it gets jammed or something, then they've got all sorts of grief. So, many

licensees have decided it is cheaper to install a repair than it is to go in and keep doing inspections all the time because the repair can be done for several million dollars and once it's done, that's it, they don't have to go back and inspect all of these horizontal welds.

What the repair does, this tie rod repair, and I've got some pictures I'll show you, is it functionally replaces all these circumferential welds. You're basically clamping this thing together on the outside. There have been two designs that have been approved to date, although my understanding is there are several other vendors that have actually developed designs and are trying to market them. So, there's a number of designs out there. Two have been contracted with and installed to date. One is with GE and the other is MPR Associates.

The repair ensures that one maintain structural integrity under all design conditions. As I said before, the plants that have used the tie rod type design to date are Hatch 1, Oyster Creek, and Fitzpatrick, with Brunswick using these small clamps just to take care of the H2, H3 weld.

Next slide, please.

[Slide.]

MR. SHERON: This is what I will characterize as a generic repair. It does not represent any actual repair

that went into a plant. It's similar, but the designs have been refined, so they look a little bit different. But as you can see, what you're doing is you're basically hooking onto the bottom where the jet pumps sit on that lower plate and clamping onto the top of the shroud. Then they tension those down and that essentially clamps it together.

The next slide, please.

[Slide.]

MR. SHERON: These are not in your package. These are some photographs. I hope you can see these. I've got some actual pictures here. I'd like to pass these around. These were taken at Plant Hatch when we were visiting there. These will just give you an idea of the size of these tie rods. The one you saw in the slide here had ten tie rods. The GE design uses four and these are one of the GE designs.

Can I see the next slide, please?

[Slide.]

MR. SHERON: The piece you see there, that clevis piece, is actually -- what that does is on the bottom where you see the gusset plates, down where the jet pump is, what they actually do is they drill a hole through the gusset plate, put a clevis pin in there and that thing comes down and grabs onto it. But that will give you an idea of the size of these things.

Could I have the next slide, please?

[Slide.]

MR. SHERON: I've talked now about the core shroud, but obviously other internals in the BWRs are susceptible to stress corrosion cracking. Let me talk a little bit about that.

When a licensee goes in to inspect the internals, they just don't look at the shroud, they look at a number of different components. They look at jet pump hold-down beams, the driers, the manway covers, et cetera. So, it's not that we've only been looking at shrouds. The shrouds have been the most significant cracking that we've seen, but there have been cracks seen in other components for some time now, jet pump hold-down, beam cracking and so forth.

One is that the utilities have been doing these inspections and when they find this cracking they have to evaluate it and either determine whether a repair is necessary or whether again it can be operated safely. Nevertheless, we have asked the BWR Vessel Internals Project, once they've gotten over this hump with the shrouds, to develop comprehensive plan that would address potential cracking at all of the internals. My understanding is they are well along on that. They have sent this in a letter recently that said they will send a detailed plan in by March, next month. My understanding is we will have their assessment in sometime this summer, I

believe around June or July.

COMMISSIONER ROGERS: What is the biggest safety problem with any internals cracking? You've told us --

MR. SHERON: Well, there's a number. One is manway covers in which -- and the other would be loose parts that are generated, obviously if you have small pieces that break off or something. Then there's a question too of if you have one piece that is cracked and another piece that happens to break loose, is there any synergistic effect.

MR. RUSSELL: The issue -- if you go back to slide 4.

[Slide.]

MR. RUSSELL: If you look between the two jet pumps, right around where the symbol for the H8 weld is, you'll see a manway cover. There are typically two of these, one on each side. We have seen cracking in the weld. The manway cover basically sits on the top and then it's a fillet weld going around the sides. We've seen that at a number of facilities, at Peach Bottom, at Browns Ferry and others. This would have the potential for losing the ability to reflood the volume because it's part of that boundary for reflooding up to two-thirds core height. This only becomes an issue if you have recirc line break. For a steam line break you can still reflood and would also not impact your core sprays because a failure down here is not

moving the shroud where you would be impacting the piping up at the top of the vessel, either the lines that are going in where you could shear those. So, it would still have the spray effectiveness where the shroud lifting or moving could cause you to lose spray as well as have a flow path. So, the shroud issue, from a safety standpoint, is the more significant.

Probably the next is associated with the manway covers. The hold-down beams, if they come loose, they could potentially damage piping, potentially impact your core spray, but it's essentially a loose part inside and it's not of the same order of magnitude as the other components.

So, we have prioritized these issues to address the shroud first. We have been addressing the manway covers as they have come up and inspection techniques have been developed to look at those and also the hold-down beams. Again, these are relatively simple devices to replace. So, from an economic standpoint, they may be better off just replacing them rather than spending time inspecting, et cetera.

It really is going to be driven by economics because if you have a manway cover that cracks or come loose, if you have problems with that, or you have a hold-down beam that comes loose and damages internal components, the facility is going to be down for some time. This is

critical path time on outages. You've got to go into refueling and lift the head. So, there are a number of economic incentives. So, we believe that we're addressing the more significant safety ones first and that's appropriate from an overall priority standpoint.

MR. SHERON: And the last bullet on that slide obviously is we have asked our Office of Research, Nuclear Regulatory Research, to perform research looking into the ability to understand and perhaps predict not only the growth and the initiation of the stress corrosion cracks but also the arrest mechanism. As I said before, we could demonstrate conclusive that once these things go outside of the heat affected zone they stop. I think that would give us a lot more assurance that we didn't have in terms of the degree of the problem.

Also, we have asked them to look at the cracking of multiple internals. Again, it's a synergistic effect to look at what are the important ones and if I had two things crack, is there a synergistic effect that I'm not aware of? We don't think there are any right now that we haven't seen, but nevertheless it's, I think, a good confirmatory thing to do.

DR. THADANI: Brian, if I may add, in terms of the other internals, we have raised the same issues with the industry. I think at this stage it does appear that the

industry is taking a very serious look trying to evaluate and understand, for example, the synergistic effects that Brian talked about. They have also shared with us the level of effort they are putting into this activity. It has gone up by more than an order of magnitude, which to me is a clear indication of how seriously they seem to be taking it. It's a lot of money they're putting in this program.

They owe us details. That means milestones, schedules and specific activities that they are undertaking as to when they will complete them, in March. To me, that's a very important time period. We're very anxious to see the details.

COMMISSIONER de PLANQUE: Going back to the growth of the cracks, given the inspections that you've seen so far, how well would what you have predicted compare with what's actually been found and how conservative were your estimates of how deep the cracks are, how wide --

MR. SHERON: One of the problems is that you really don't know when they initiated.

COMMISSIONER de PLANQUE: Right.

MR. SHERON: Okay. That's the big problem. If you knew when they initiated, then you would be able --

COMMISSIONER de PLANQUE: Then the curves are easy.

MR. SHERON: Yes, that makes it real easy.

COMMISSIONER de PLANQUE: Right.

MR. SHERON: Right now we use a conservative bound on that.

I don't know, Ed, maybe you want to add a little bit to --

MR. HACKETT: The one foreign plant that we have data where they have tracked a crack from -- I guess it's over two cycles now is growing very much slower than the conservative value we're forcing the industry to use. So, that's something, we're looking at trying to accumulate that kind of data. On the other hand, a lot of the plants are putting in these repairs. So, we're not likely to be getting a whole lot more field data here. That's the one data point that we have and that shows that it's pretty conservative.

COMMISSIONER de PLANQUE: Okay. And in terms of the factors that you plug in, the water chemistry, et cetera, do they seem to be fairly in line with what your thinking is in terms of effect or can't you really tell from the data available?

MR. HACKETT: That's a much tougher question because you're asking, I guess, about --

COMMISSIONER de PLANQUE: The second order.

MR. HACKETT: -- another level of synergism here between the water chemistry, the material and so on. So

far, as we were talking about earlier, the strongest correlation we seem to have is with the conductivity over the early operating years for the plants. In other areas, like the residual stress level that Brian was referring to, we don't have that quantified anywhere near as well. So, it's difficult to say. The strongest correlation is with the conductivity at this point.

COMMISSIONER de PLANQUE: Okay.

MR. SHERON: And could I have the last slide, please?

[Slide.]

MR. SHERON: Where are we going from here? Well, first off, we will continue to review the inspection results. Plants will still come down and do inspections. Even though some will come in and do preemptive repair, there may be reasons why they don't want to do the repair at this time. So, if a plant chooses to do an inspection again, we want to be on top of it. We will be reviewing it.

We also want to look at the inspection plans before a plant goes into an outage so we don't get into one of these last minute arguing about how much they should inspect and so forth. We'd like to get that all sorted out way before they ever bring the plant down and go in, so they know what they're going to do when they go in, they know what they're going to do when they find certain cracking and

so forth.

The other thing we want to do is we would like to issue a summary report, NUREG report on this whole issue. So, if somebody wanted to get a real comprehensive assessment of this whole issue of BWR shroud cracking and so forth, they can go to this NUREG and it would kind of lay out the whole history for them.

We are also doing a comprehensive assessment, as I said before, as Ashok said, of all of the BWR internals. Okay. The shroud again was the most important, but we need to look further at all the internals to make sure we understand where the most susceptible ones are, what the consequences of that kind of cracking is and to make sure there's nothing out there that we're not aware of.

Lastly, we will be reviewing the repairs. These repairs are not ASME code repairs in the sense that they are not restoring it to its original condition and that requires the licensee to make a submittal to the staff under 50.55(a). So, we will be doing reviews of repairs and then writing the safety evaluations on those.

Lastly, which is not on here, obviously once you put a repair in, you can't ignore it forever. Now the question is we have to inspect the repairs. The question is what needs to be inspected and how often and we are right now working, developing a plan for that.

That concludes my presentation. If there are any questions, we'll try to answer them.

CHAIRMAN SELIN: Is the cause of the cracking all ancient chemistry or is there still corrosion going on? In the current plants, in the current chemistry, do we still see contributions of corrosion or is this the residue of poor chemistry and a longer time?

MR. SHERON: I think this is just -- you know, there's really nothing there from the erosion. It's mostly just from the water chemistry, the cracking.

Is that your understanding?

MR. HACKETT: That's correct. It's probably too early to tell, if your question is aimed at some of the newer plants. For instance, on water chemistry, any level of conductivity in the water is enough to cause this phenomenon. You probably can get it, it will just take an awful lot more time. Certainly there's the correlation with the high conductivity that seems to cause the initiation very early, but at this point we don't know for the other plants where they're going to go. That's why it's very important I think at this point to emphasize mitigation efforts for those plants.

CHAIRMAN SELIN: I'm not sure everybody in the industry, including us, too this really quite as seriously as it might have been taken in the beginning.

MR. TAYLOR: We did meet with the owners. I can't recall the date of that meeting, and we called that as soon as we felt we were ready and that was a very productive meeting which I think caused the owners to universally get behind this project.

CHAIRMAN SELIN: So there's not a catching people's attention problem?

MR. TAYLOR: I think we have their attention.

MR. RUSSELL: I think the industry was surprised when they saw the extensive of the cracking at Dresden and Quad Cities and they may have thought that Brunswick was an outlier for some reason. But once you started to see it at more facilities and the interaction back and forth with the staff that first time around to justify and review, for the licensee to provide the justification and us to review, why it was okay to continue operation with this extensive cracking when the consequences of being incorrect could be quite significant was a very long and involved process. There was quite a bit of dialogue back and forth with senior managers of Commonwealth Edison and senior utility managers to make sure that this was, in fact, focused upon. I think they have done a good job of it. They recognize that this was an issue that the owners needed to get together and address and not just leave to a particular vendor to address.

CHAIRMAN SELIN: If you talked to the people overseas that run boilers and have seen this, do you get any different picture from the one that was presented today?

MR. RUSSELL: I've had discussion with the regulators in one country that has been monitoring the cracking for some time and that cracking is less significant than what we've seen. They are, in fact, mapping it and monitoring it and the growth rates appear to be less than what we would see. Based upon analysis we've done, I have no reason to question their conclusion about why it's acceptable and continue to operate without installing a repair. The issue becomes one at some point it's going to cost them more to continue to inspect than it would be to do a preemptive repair and not continue to inspect.

DR. THADANI: And yet there's another country, they have seen a fair amount of cracking and their inclination, as I understand now, seems to be to actually replace the shroud. It's a different design. It's bolted down instead of being welded at the bottom. The utility -- right now there seems to be some question as to what the utility is actually going to do because one source indicated to us -- when I was there actually and spoke with the regulators, they said the utility was planning to replace the shroud. There seems to be some question about that now, but nevertheless there is another example.

CHAIRMAN SELIN: Commissioner Rogers?

COMMISSIONER ROGERS: Yes. Have you come to an agreement with the licensees on what constitutes an acceptable inspection program for this? Do you have to thrash this out with each individual licensee or have you been able to come to some general agreement?

MR. SHERON: I think we have general agreement, but I would not guarantee that there would not be circumstances in which they would like to negotiate some more on it. Again, it's a matter of they really don't know what they're going to find until they open up the vessel and go in and look. That's when they run into problems with either the equipment breaking down or they find out, like I said, the shroud is not round or they forgot the fact that the gap between the shroud and the vessel is too narrow for the equipment to fit and stuff. Then you've got to get into these discussions.

But right now, our going imposition is we think they should do 100 percent of the accessible welds. I use the word "accessible" because you have to remember if you look at these pictures, there's a lot of garbage sitting around these welds. Okay?

MR. RUSSELL: Important safety-related --

MR. TAYLOR: Not garbage, Brian.

MR. SHERON: Wrong term. But there is a lot of

stuff sitting there that they cannot really get a good picture of these welds. Some of them even have bands around them, as I understand, and so forth. So, you can only see one side. Core spray piping is up there that you can't get behind to see some of them. So, when we say accessible, it's not necessarily the whole weld, it's just the part of it that can be seen.

MR. RUSSELL: Early on we had a lot of dialogue back and forth on scope of inspection. That's why it's important for them to describe to us what their actual inspection plans are 30 days prior to and resolve those issues before you get into a critical path situation. So, they have learned and we have learned from that process and I think it's fairly well understood now that our expectation is that that which can be inspected you should inspect unless you're going in to do a preemptive repair and we review and approve the repair.

COMMISSIONER ROGERS: Well, it sounds like you've gotten on top of the problem and it seems to be well in hand. Very good. Thank you.

COMMISSIONER de PLANQUE: You've answered my questions. Thank you.

CHAIRMAN SELIN: Thank you very much for a timely report.

[Whereupon, at 3:01 p.m., the meeting was

concluded.]

CERTIFICATE

This is to certify that the attached description of a meeting of the U.S. Nuclear Regulatory Commission entitled:

TITLE OF MEETING: BRIEFING ON CORE SHROUD ISSUES - PUBLIC MEETING

PLACE OF MEETING: Rockville, Maryland

DATE OF MEETING: Wednesday, February 1, 1995

was held as herein appears, is a true and accurate record of the meeting, and that this is the original transcript thereof taken stenographically by me, thereafter reduced to typewriting by me or under the direction of the court reporting company

Transcriber: Carol Lynch

Reporter: Peter Lynch

INTERGRANULAR STRESS CORROSION CRACKING OF BOILING WATER REACTOR CORE SHROUDS (GENERIC LETTER 94-03)

February 1, 1995

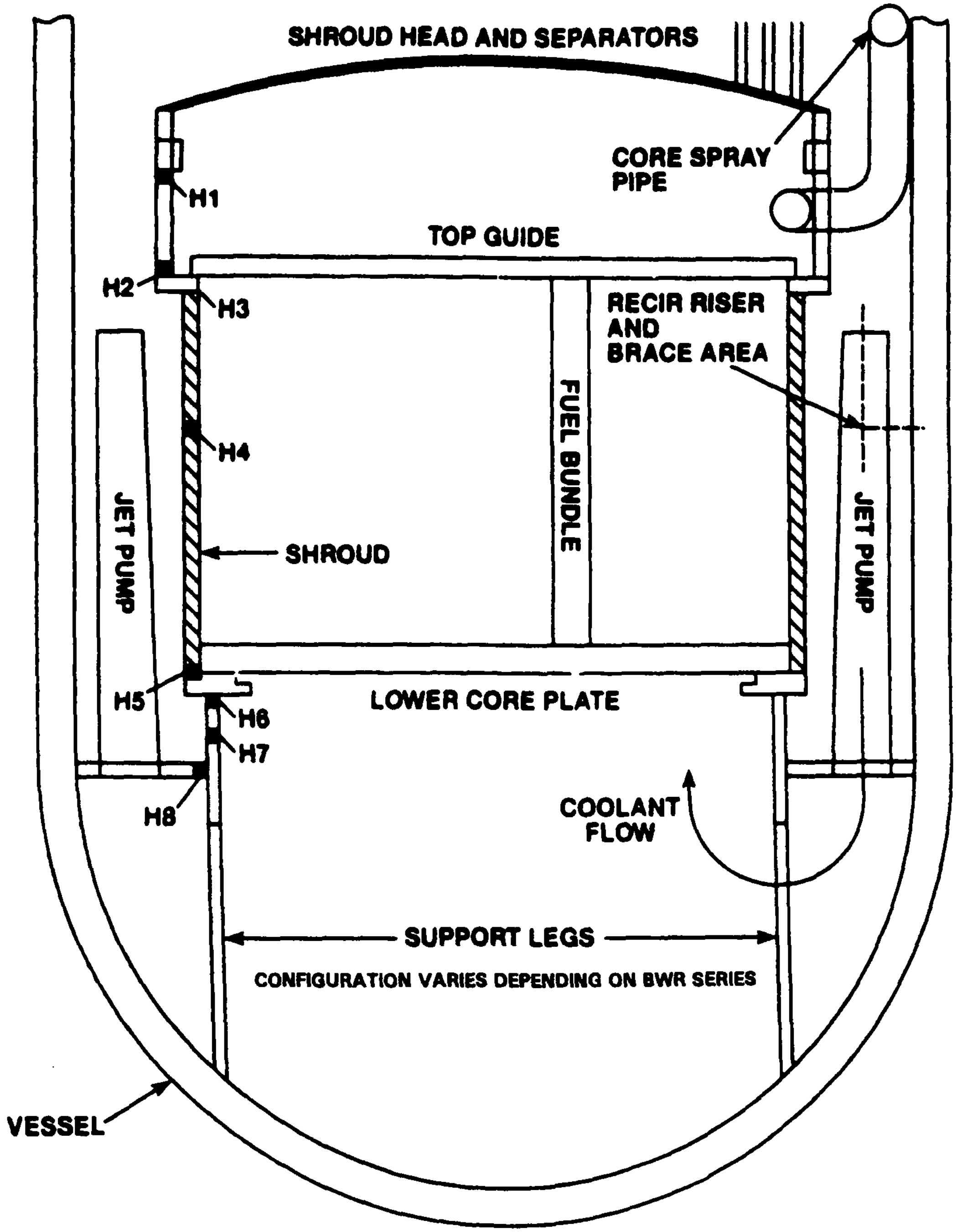
Brian W. Sheron, Director
Division of Engineering, Office of Nuclear Reactor Regulation

Lead Technical Contacts:
E. Hackett, NRR, 504-2751
K. Kavanagh, NRR, 504-3743

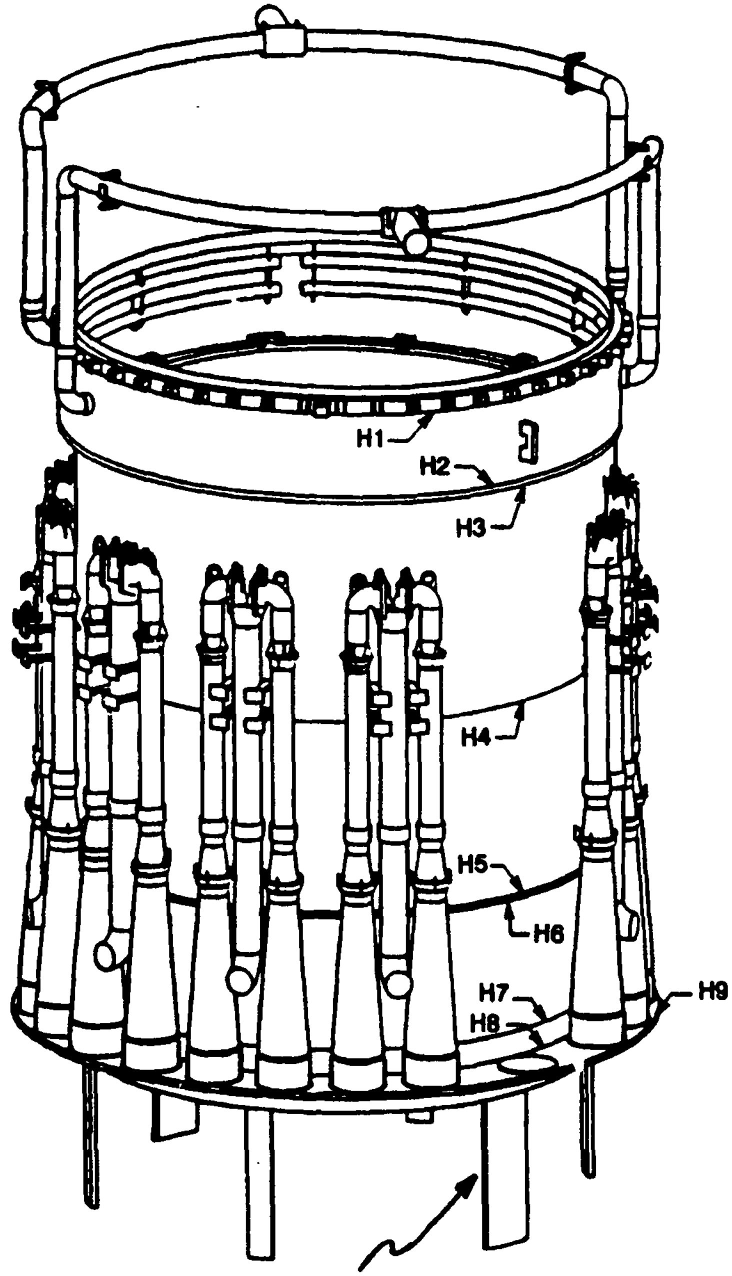
STRESS CORROSION CRACKING OF BWR CORE SHROUDS

- Background (Commission Papers - 1/3/94, 11/10/94)
- Initial Observations of Shroud Cracking in U.S. Plants
- Safety Significance
- Regulatory and Industry Actions
- Current Status
- Stress Corrosion Cracking Susceptibility Criteria
- Susceptibility Ranking of BWRs
- Inspection Experience
- Core Shroud Repairs
- Comprehensive Assessment of BWR Internals Cracking
- Future Actions

CORE SHROUD STRUCTURAL CONFIGURATION



CORE SHROUD WELD LOCATIONS



SUPPORT CONFIGURATION VARIES DEPENDING ON BWR SERIES

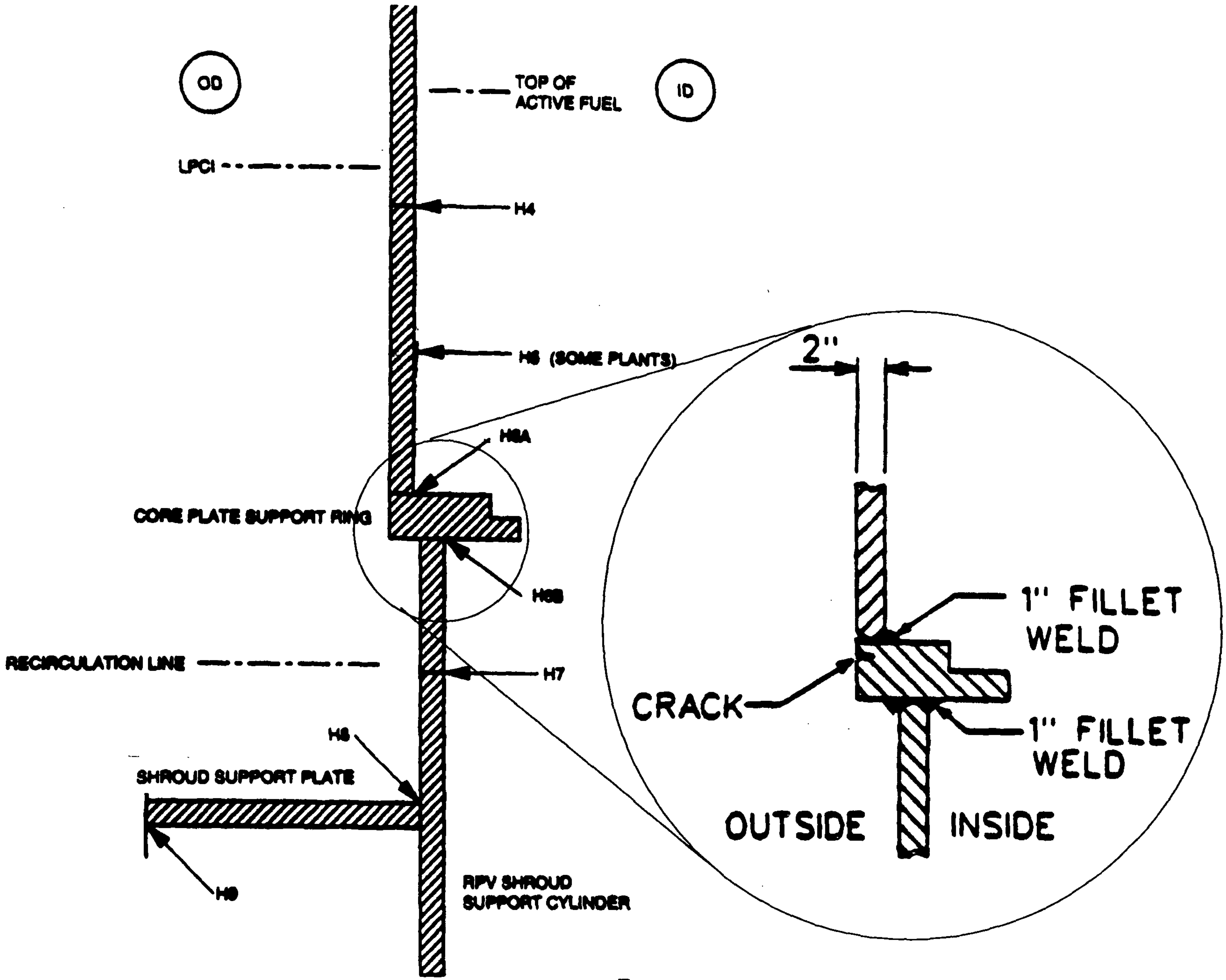
BACKGROUND - CORE SHROUD FABRICATION

- Shroud Material is 304 or 304L Stainless Steel
- Typical Dimensions
  - 14 to 17 Feet in Diameter
  - Wall Thickness (1.5 to 2 Inches)
- Construction
  - Welded Plates
  - Welded Plates + Ring Forgings
- Fabrication Involves Both Circumferential and Axial Welds
- Residual Stresses are Present from Welding
- Weld Heat Affected Zones Particularly Susceptible to IGSCC

INITIAL OBSERVATIONS OF SHROUD CRACKING IN U.S. PLANTS

- Significant Shroud Cracking First Observed at Brunswick Unit 1
- Discovered During GE-Recommended Visual Examination of Internals
- Cracking at Weld H3 on the Inside of the Top Guide Support Ring
- Extent of Cracking was 360°, with a Maximum Depth of 1.7 Inches
- Similar Cracking in the Core Plate Support Ring Subsequently Observed at Dresden Unit 3 and Quad Cities Unit 1

SHROUD CRACKING IN CORE PLATE RING



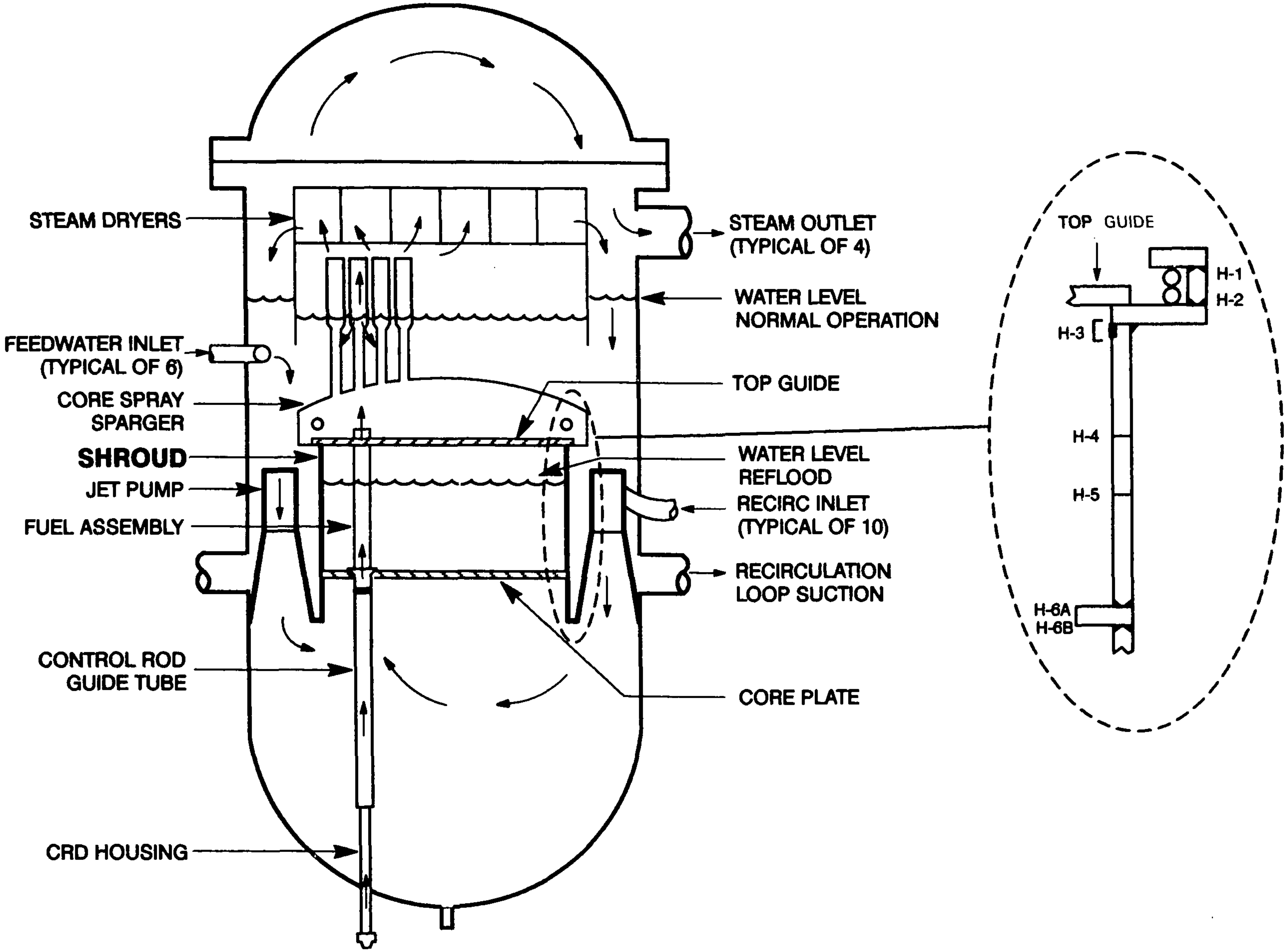
SAFETY SIGNIFICANCE

- Only a Concern if Cracking is 360° Through-Wall
  - Potential for Shroud Separation

- Normal Operating Conditions
  - Through-Wall Cracks at Upper Elevation Detectable By Core Flow/Power Mismatch
  - Through-Wall Cracks at Lower Elevation May Not be Detectable

- Accidents of Concern are Main Steam Line Break, Recirculation Line Break and Safe Shutdown Earthquake
  - Uplift of Top Guide
  - Interference with Control Rod Insertion

REACTOR VESSEL FLOW PATHS



REGULATORY ACTIONS

- Information Notice 93-79 (September 30, 1993)
- Information Notice 94-42 and Supplement 1 (June 7/July 19, 1994)
- Generic Letter 94-03 (July 25, 1994)
  - Inspect/Repair Shroud at Next Refueling Outage
  - Provide Safety Assessment Justifying Operation Until Inspection/Repair
  - Provide Inspection/Repair Plans 30 Days Prior to the Outage

INDUSTRY ACTIONS

- GE Service Information Letters
- Formation of BWR Vessel and Internals Project (BWRVIP)
- BWRVIP Subcommittees:
  - Integration
  - Inspection - Topical Report (9/2/94)
  - Assessment - Topical Report (9/2/94)
  - Repair - Topical Report (8/18/94)
  - Mitigation

CURRENT STATUS

- Key Factors Affecting Relative IGSCC Susceptibility for BWRs Established
- Staff Met with EPRI and BWRVIP to Discuss Scope of Core Shroud Inspections
- Analysis of Inspection Results Continuing
- Staff Continues Plant-Specific Assessments for Repair Acceptability
- NRR Review of Generic Letter 94-03 Responses Completed

GL 94-03 CONCLUSIONS/BASES FOR CONTINUED OPERATION

- No 360° Through-Wall Cracking to Date
- No Symptoms (Power to Flow Mismatch) of Through-Wall Cracking Have Been Identified During Power Operation
- Small Ligament Required for Adequate Structural Integrity
- ASME Code Margins Satisfied
- Low Frequency of Initiating Event
- Short Period of Operation Until Inspection can be Performed
- Plant-Specific Factors (Four Highest Susceptibility Plants)

STRESS CORROSION CRACKING SUSCEPTIBILITY CRITERIA

- Operational Time
- Reactor Water Chemistry (Conductivity)
- Materials (Carbon Content)
- Shroud Fabrication Methods
- Weld Stresses

SUSCEPTIBILITY RANKINGS

- Category "A" BWRs (8 Units)
  - Less Than 8 On-line Years of Operation
  - Good Initial Water Chemistry
  - Low Carbon Materials (304L)
- Category "B" BWRs (6 Units)
  - More Than 8 On-line Years of Operation
  - Good to Moderate Initial Water Chemistry
  - Low Carbon Materials (304L)
- Category "C" BWRs (22 Units)
  - More Than 6 On-line Years for BWRs with Shrouds Fabricated from 304 SS; 8 Years for Those Constructed using 304L
  - Moderate to Poor Water Chemistry

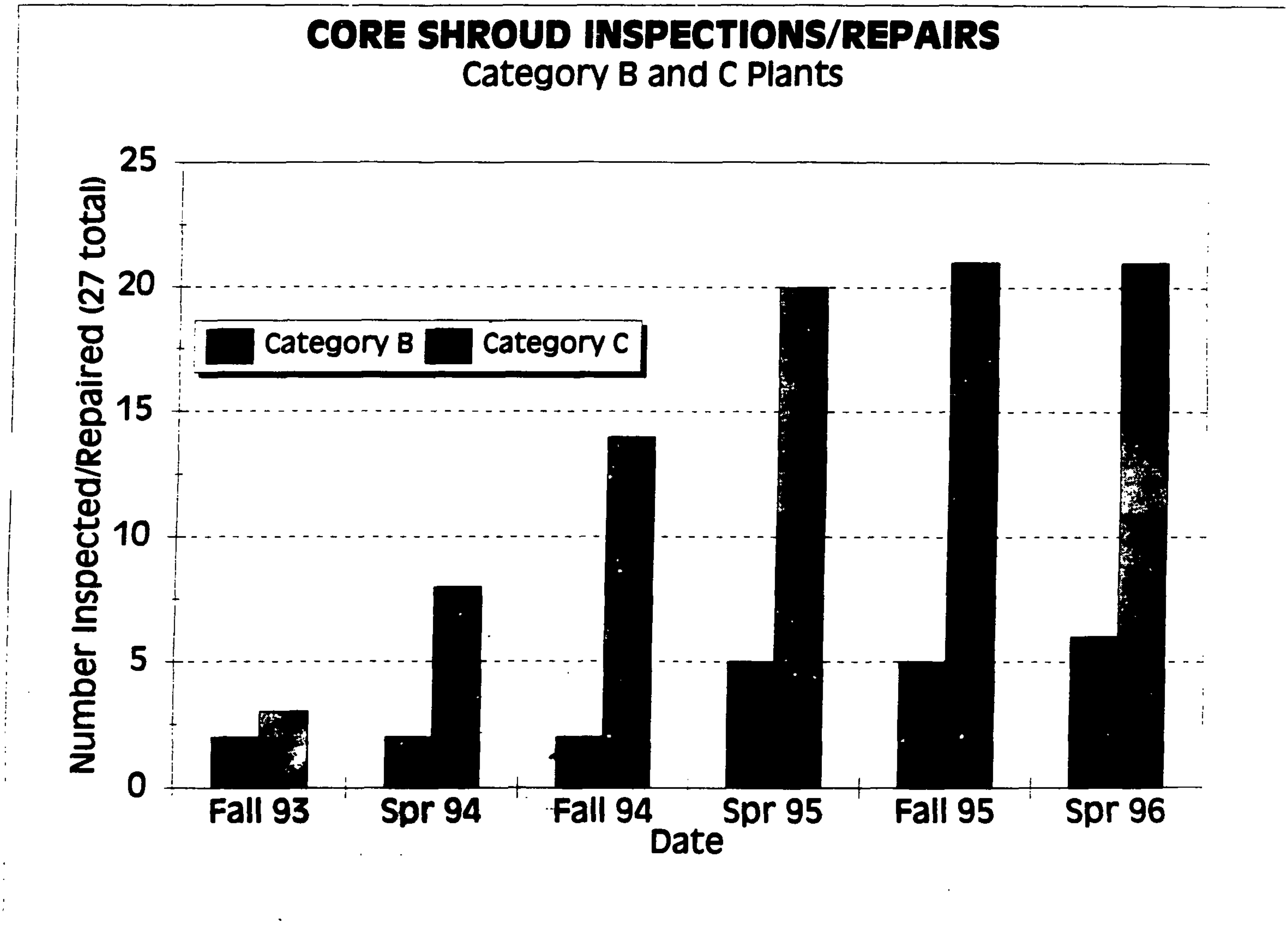
MOST SUSCEPTIBLE PLANTS

- The Staff Concluded that 11 of the 22 Category C BWRs had the Potential for Containing Significant Cracking
- Conditions at These Plants Bounded All Other BWRs

Plant	Inspection	Repair
Pilgrim		4/95
Dresden 2		5/95
Quad Cities 2		4/95
NMP-1	2/95	2/95
Dresden 3	Complete, 4/94	3/96
Quad Cities 1	Complete, 4/94	9/95
FitzPatrick	Complete, 1/95	Complete, 2/95
Oyster Creek	Complete, 10/94	Complete, 11/94
Brunswick 1	Complete, 10/93	Complete, 1/94
Brunswick 2	Complete, 5/94	Complete, 6/94
Hatch 1		Complete, 10/94

OVERALL INSPECTION RESULTS TO DATE

- 13 of 22 Category C Plants Inspected
  - 360° Circumferential Cracking at Four Units
  - No 360° Through-wall Cracks Identified
  - Cracks Primarily Found in Core Shroud Rings
  - The Required Structural Margins of the ASME Code were Satisfied for all Identified Cracks
- 2 Category B Plants Inspected
  - No Cracking Identified
- 1 Category A plant inspected (Fermi 2)
  - No Cracking Identified
- Most licensees of Category B and C BWRs will Complete an Inspection or Repair by Fall 1995



Total Category C = 22 plants*

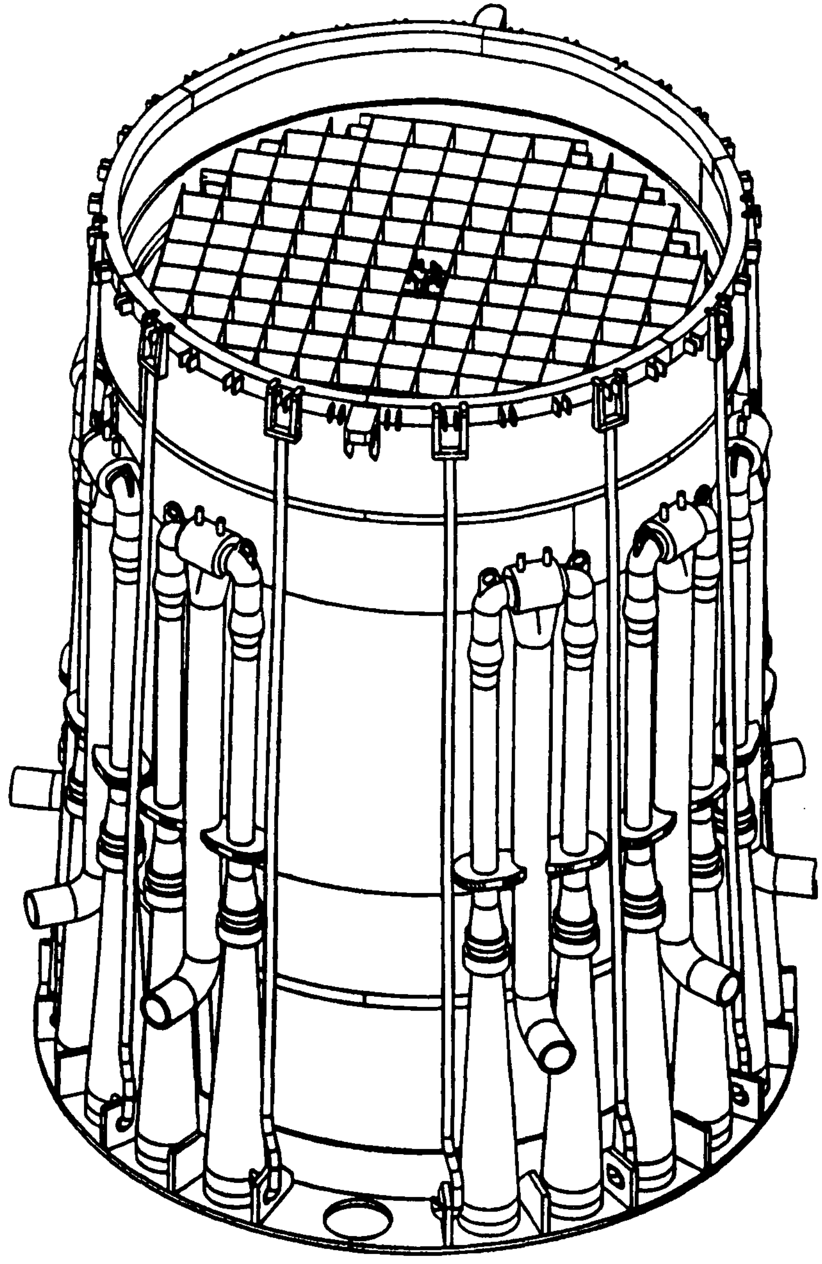
Total Category B = 6 plants

* - Browns Ferry 1 is not operating and is not reflected in the graph

CORE SHROUD REPAIRS

- If Cracking is Identified Licensees May:
  - Evaluate Analytically to Demonstrate Structural Margin
  - Install Repair Option
- Considering Economic Factors in Addition to Susceptibility, Some Licensees Have Decided to Initiate a Preemptive Repair
- Repair Functionally Replaces Shroud Circumferential Welds
- Several Tie Rod Restraint Systems Have Been Developed, Two Designs Have Been Approved to Date
- Repair Ensures Structural Integrity for All Design Conditions
- U.S. Plants Repaired to Date Using Tie Rods:
  - Hatch 1
  - Oyster Creek
  - FitzPatrick

NUCLEAR POWER PLANT PROPOSED REPAIR TO REACTOR SHROUD



Photograph - Plant Hatch Repair (Tie Rod)

Photograph - Plant Hatch Repair (Lower Clevis Forging)

COMPREHENSIVE ASSESSMENT OF CRACKING IN BWR INTERNALS

- Other BWR Internals Are Susceptible to IGSCC
- Inspections and Evaluations of These Components Have Been and Are Continuing to be Conducted
- Staff has Requested the BWRVIP to Develop a Comprehensive Plan Addressing Potential Cracking in All BWR Internals
- January 1995 Commitment Letter Received from BWRVIP, Detailed Plan to be Submitted in March 1995
- NRR User's Request to Office of Research (December 1994)
  - Growth/Arrest of IGSCC Cracks
  - Effects of Cracking in Multiple Internal Components

FUTURE ACTIONS

- Continue Review of Inspection Results
- Review Licensee Inspection Plans Before Plant Outages
- Issue Summary NUREG Report
- Comprehensive Assessment of all BWR Reactor Vessel Internals
- Review Repairs