Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title: Expert Panel Workshop on Degradation of Concrete in Spent Nuclear Fuel Dry Cask Storage Systems

Docket Number: (n/a)

Location: Rockville, Maryland

Date: Tuesday, February 24, 2015

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NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR REACTOR RESEARCH

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EXPERT PANEL WORKSHOP ON DEGRADATION OF CONCRETE IN SPENT NUCLEAR FUEL DRY CASK STORAGE SYSTEMS

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PUBLIC MEETING

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TUESDAY,

FEBRUARY 24, 2015

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The meeting was convened in the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, Rockville, Maryland, at 8:30 a.m., Sheila Ray and Christopher Jones, moderating.

PANEL MEMBERS PRESENT:

NEAL BERKE, Tourney Consulting Group

LAURENCE JACOBS, Georgia Institute of Technology

RANDY JAMES, Structural Integrity Associates

JOHN POPOVICS, University of Illinois

YUNPING XI, University of Colorado

NRC STAFF PARTICIPANTS:

SHEILA RAY, NRC/NRR, Facilitator

CHRISTOPHER JONES, NRC/RES, Moderator
GREG OBERSON, NRC/RES, Materials Engineer
RICARDO TORRES, NRC/NMSS, Materials Engineer
BOB TRIPATHI, NRC/NMSS, Sr. Structural Engineer
AL CSONTOS, NRC/NMSS, Branch Chief
MARK LOMBARD, NRC/NMSS, Division Director
BRIAN THOMAS, NRC/RES, Division Director

NRC CONTRACTOR PARTICIPANTS:

LEO CASERES, Southwest Research Institute (SwRI)
ASAD CHOWDHURY, Center for Nuclear Waste Regulatory Analyses (CNWRA)

T-A-B-L-E O-F C-O-N-T-E-N-T-S

dry cask storage systems are far less than the radiation dose that's seen in the bioshield walls, in a PWR for example. And so that's probably a good thing.

There's a recent NUREG/CR that's been published from the Oak Ridge folks. Numbers listed there.

And there's some evidence, from the Japanese guys, that the -- that was pretty vague. From some Japanese researchers that there is some coupling with ASR.

And so you can morph the, what would otherwise be non-soluble silica phases, into something that is soluble. And that, you know, there maybe a coupling effect there. So that again brings up this little coupling thing that we have in the back of our minds.

So here again, and you know the best question first, are total lifetime fluence limits adequate to ensure performance?

MR. POPOVICS: I would say no. Because those limit -- that assumes that the limits are well established and well understood. And I don't believe they are.

And there are other factors besides

fluence. There's temperature, there's what, flux. There's a number of things that, again, I agree the level are low here. But I, you know --

MR. JONES: Yes.

MR. POPOVICS: -- sort of say, okay, here's a number. Let's say with ASR. Okay, here's the number. It's a reasonable number from expansion, because you know formation cracks, you can define it on something physical.

I have a hard time saying, okay here's the single number and define that. You know, that can capture all the cases.

MR. XI: You know, in my answers, so I provided two different answers. One is if you ask within 40 years period. So the ACI specified value is fine.

It's about --

MR. JONES: In the shorter timeframe.

MR. XI: Yes. In the seven years, 40 years. About six orders of magnitude lower than the critical value identified in the paper by Hilsdorf.

MR. JONES: Yes.

MR. XI: Published in 1978. So worldwide the standard was based on that paper.

So you can talk about 300 years and that's different story. Because it's another rate, is a total of both.

MR. JONES: Okay.

MR. XI: For neutron radiation. So that's why for 300 years the answer is I don't know.

MR. JONES: Okay.

MR. XI: Actually, you mentioned that report recently published. That's what I did with my colleague.

MR. JONES: Right.

MR. XI: So we searched all the literature. And actually we analyzed all the references cited by Hilsdorf.

So a lot of test done in the past is not reliable. So --

MR. JONES: For numerous reasons, as I recall, some were --

MR. XI: Yes.

MR. JONES: -- strange aggregates or strange cements.

MR. XI: Yes. Sometimes it's done, even for cement. The results are included in the paper and used worldwide by many countries. Including here.

So that's why 300 years is, I don't know.

MR. JONES: Yes, maybe.

MR. XI: 30 years, that's fine. The ACI standard is fine.

MR. JONES: Somebody was talking, I don't know if there was some more?

MR. JACOBS: No, Larry just -- well I'll let you. So there was a paper that just came out, two papers, out of the Oak Ridge folks.

MR. JONES: Sure.

MR. JACOBS: A very nice summary. I saw this after I printed my response.

MR. POPOVICS: Yes, I found this yesterday.

MR. JACOBS: Again, one of the authors I know, Yann Le Pape.

MR. POPOVICS: Yes.

MR. JACOBS: And it's a very nice summary and it does a very good job. And I literally was reading it on the plane on the way in last night.

And I don't have my arms around it quite honestly, but I think this is one -- this is one of the reasons I said, gee, a single number doesn't make sense. They're too many variables going on.

MR. JONES: Okay.

MR. JACOBS: But I think it echoes a lot of the things we're saying. Yes.

MR. POPOVICS: The reason that I kind of don't have a lot of confidence in the total fluence on this is because even, you know, Hilsdorf paper, regardless of, you know, the problems that may be associated with it.

I think over the years, and in the different documents, it's interpreted differently. So these numbers don't have the same meaning to all people.

So for example, I pointed out that in Hilsdorf paper, he cited some levels as critical levels of fluence. Above which you're causing damage. That's what I understand it to be.

Whereas in the ACI 349 document, that's taken as an ultimate lifetime limit. These are two very different things.

And also there's a little bit of confusion about the units in those. So for example, I think Hilsdorf uses, I think it's neutrons per square meter. But --

MR. XI: It's per centimeter.

MR. POPOVICS: No -- well ACI is using square centimeter and Hilsdorf is using square meter.

MR. XI: No, no. Hilsdorf's using --

MR. POPOVICS: So maybe I switched it. But one -- they're not using the same units.

Now it's reading that two, I started to be concerned like, maybe someone didn't catch that in ACI so that when they put the limit. Because actually the lifetime limit they put on, because they're using differences much higher than Hilsdorf's limit, if I read correctly.

So these kinds of things give me concern that we hang our hat on a limit when these are old data as far -- I mean we should -- I should look through Le Pape's paper. I haven't -- I just found that yesterday, to get a better handle on that.

But otherwise there hasn't been a lot of, that I've seen, a lot of research on radiation exposure, since Hilsdorf's. And that was around '78.

MR. BERKE: There was a Japanese paper that I found, I don't remember the names of the guys, that looked at this. And they also looked at, they were a little bit -- they were okay on the neutron flux, but they seemed to think that the radiation was a little bit too low.

MR. JONES: You're talking about the --

MR. BERKE: It should be lower.

MR. JONES: -- gamma part?

MR. BERKE: The gamma part is probably lower than what's typically done. But it's our -- but that was all by calculation, the gamma.

But what they intended to show was that there was a big -- what the effect is was there was a combined effect with the radiation and the heat temperature of the concrete.

So if the concrete stayed below a certain temperature, these levels were fine. But if the concrete temperature was higher, these levels were --

MR. JONES: The levels changed with --

MR. BERKE: Yes, they were not necessarily fine.

MR. JONES: So let me go back to the -- so you're bring up kind of a second point. So I asked a very generic question, intentionally.

But you're actually thinking that maybe the fluence limits themselves may have issues in the way they've been interpreted and --

MR. POPOVICS: I don't want to accuse anybody --

MR. JONES: Sure. No, no, no.

MR. POPOVICS: But they cause me a lot of confusion.

MR. JONES: Okay.

MR. POPOVICS: That first of all, one is listed as a critical limit of fluence for material breakdown whereas the other is listing that limit as an acceptable lifetime dose.

MR. JONES: Okay.

MR. POPOVICS: These are two different things.

MR. BERKE: Well that's more conservative. The second one.

MR. POPOVICS: Right. And that the units that are presented, as far as I can read, make the opposite sense.

To one, ACIs that list as acceptable lifetime, is orders of magnitude higher because it's units of neutron per centimeter square, not meter squared. But yet the same number is quoted.

So I'm wondering if there is some accounting error. A typo there.

MR. XI: No, no. Actually I did the same analysis.

MR. POPOVICS: Okay.

MR. XI: And I convert the ACI number to the same unit as he used. It's a neutron per centimeter square. And the ACI number is more conservative.

MR. BERKE: It is more.

MR. XI: It is fine.

MR. BERKE: Yes, the meter squared number is much bigger than the 70 square meter squared number.

MR. POPOVICS: Yes, but Hilsdorf --

MR. BERKE: It had to be at least 10,000 counts larger.

MR. XI: Yes, I analyzed in my answer.

MR. POPOVICS: Okay.

MR. XI: It's fine.

MR. BERKE: Yes, I mean I looked at that. Because they have like, the ACI I think was 10 to the 17 neutrons per meter squared.

MR. XI: Yes.

MR. JONES: Neutrons per meter.

MR. BERKE: Neutrons per meter squared. And --

MR. JONES: So it --

MR. BERKE: -- these Japanese guys came up with 12 times 10 to 22 neutrons per meter squared.

MR. XI: Yes.

MR. JONES: Yes, we can have this issue where we're concrete guys that are not as well prepared for the transition of radiation topics.

MR. POPOVICS: So you're right. Here's I'm looking at, this is the Hilsdorf paper. So the units, he's talking about the order of 10 to the 19 neutron per centimeter square.

MR. BERKE: Now you multiple by 10,000.

MR. POPOVICS: But now the ACI limit is the same.

MR. BERKE: Yes.

MR. POPOVICS: Right?

MR. BERKE: Yes. The 10 to the 17 neutrons.

MR. POPOVICS: Yes, so they do make that conversion. Okay. Yes, so the order of two should be the change.

MR. TRIPATHI: Have any of the experts had a chance to look at the recent, by recent I mean a couple years ago Brookhaven National Lab, BNL, did a nice report on this.

And from what I recall, I reviewed that report for the research folks and I recall that probably for the dry cask storage system, because of the radiation level compared to the main power block containment are so low, that we don't need to really, you know --

MR. POPOVICS: That may be, but the question is, can we rely on lifetime limits.

MR. TORRES: That's --

MR. POPOVICS: I think that's a different question.

MR. TORRES: That's not necessarily the case for up to 100 years, Bob.

MR. POPOVICS: Yes.

MR. TRIPATHI: They can get pretty close. In the gamma dose rate. It's pretty close to the limits.

MR. BERKE: Yes, I think the gamma one was the one that --

MR. TRIPATHI: The gamma was --

MR. BERKE: -- take the neutron --

MR. JACOBS: It was the gamma. At least in the Le Pape, which was a summary of all of these.

MR. JONES: So I guess let me ask my second question with a couple of different flavors. So there's some that couple with ASR, do we think that it might couple with other things? That's one question.

Do we think that the neutron and gamma act independently or should those be considered in a coupled sense? Is there any evidence that is important?

So they're sort of two separate questions there that I'll draw out.

MR. XI: Now it's acting independently.

MR. JONES: It's not independent?

MR. XI: Yes. Because when you have a neutron and then the neutron radiation generates gamma radiation.

MR. JONES: Sure. Yes.

MR. XI: Yes, so that's why when you run the test for a neutron radiation, and then at the same time you have a gamma ray.

MR. JONES: Okay.

MR. XI: So in the literature, people already realized that. So it's very difficult to separate the two effects.

MR. JONES: So the basis for making these limits sort of include the coupled effect?

MR. XI: Yes. These are already included in the coupling effect. Coupled between the two --

MR. JONES: Yes. Right.

MR. XI: -- radiations. There are also other couplings. Coupling with ASR, coupling with freeze/thaw. So that's a different coupling.

MR. JONES: So let's go into that a little bit. Do we -- so I mean you've answered my question, but are there any other examples that come to mind that radiation is expected to interact with, I guess, or --

Is that question clear? That what other mechanisms you expect radiation to interact with, I guess?

MR. BERKE: One of these guys said there was a strength degradation if the temperature was already hot.

MR. JACOBS: And there seems to be an expansion mechanism to -- from an aggregate. And it seems to be very aggregate dependent.

MR. JONES: Yes.

MR. JACOBS: So again, you can see a lot of the, like the ASR. Even the DEF could be something, you know.

There's possible for the -- so you could talk about our friend freeze/thaw, yet either, which would be another one that, you know, sounds like.

MR. JONES: So you're getting to the fact that since the aggregate expansion, you know, the most commonly identified mechanism --

MR. JACOBS: Yes.

MR. JONES: -- does the same thing in

something like DEF or does the same thing as ASR. There could be a stacking of --

MR. JACOBS: It will be a linear.

MR. JONES: Yes.

MR. JACOBS: It will be a, you know, they'll --

MR. JONES: Okay.

MR. XI: So it appears the coupling with a similar stress. So that's why it's difficult to analyze the test data in the literature.

So if some people, when they run the radiation test, they also run the temperature test. So the temperature will follow exactly the thermal history of the concrete, in the concrete, under the radiation.

And then they subtract the thermal --

MR. JONES: Subtract off the thermal effect?

MR. XI: Yes.

MR. JONES: Just get --

MR. XI: And then you get the net effect formulation.

MR. JONES: Okay.

MR. XI: But most of the test data of the meters, they don't do that. So that's why it's all --

MR. JONES: So you're --

MR. XI: -- mixed together. So first is a gamma ray and neutrons mixed together.

MR. JONES: Okay.

MR. XI: And then mixed together with a similar effect.

MR. JONES: Okay.

MR. POPOVICS: Then you get the effects on the bound water, internal water?

MR. JONES: Yes.

MR. CASERES: How about the formation of or the affect of carbonation induced by radiation?

I read some papers that talk about internal carbonation not being on the air gas phase or through a normal carbonation through the air. But rather carbon induced radiation that promotes carbonation.

MR. POPOVICS: I don't know that.

MR. BERKE: I wonder what the mechanism would be.

MR. CASERES: Iron 3 calcite reacts, I mean you have to have water in the system as well. But there's a -- transformation affects transformation of calcite into the formation of CO2, carbonation induced radiation.

MR. POPOVICS: So you're deliberating gas?

MR. CASERES: In theory.

MR. BERKE: Okay, that might be the case of a limestone aggregate or something versus a siliceous aggregate. Or I can see if you get a high enough temperature your limestone aggregate starts to break down.

MR. POPOVICS: That's pretty high.

MR. BERKE: Well --

MR. POPOVICS: You have to --

MR. BERKE: Localized flux, you know, maybe.

MR. JONES: Yes.

MR. BERKE: I mean that might be where the high temperature effect comes in. I don't know.

It's something that takes place ahead of your -- if you're at a high temperature then when this happened, you're more likely to have this. Whereas high flux or low temperature doesn't have the energy to do that.

MR. JONES: So in a very generic sense, suffice to say that dumping all this extra energy in may have effects on other mechanisms that are dependent on thermodynamic equilibria, things like that. It's, you know, not beyond the realm of possibility for a lot of the mechanisms. Maybe you can say it that way.

Let me play cattle driver and heard us along a little bit. To freeze/thaw. Thanks for the transition.

And so this, you know, I think we have a general sense of this from our, you know, understanding about how rocks erode and things like this. But, you know, water gets into the pore network, freezes, expands. There's a differential expansion thing going on that causes a tensile stress and, you know, can degrade the concrete.

We typically link this with cycles of freezing. In other words, just freezing once.

A very cold climate where it just freezes once, stays cold all winter, and then warms up. It's not as penalizing as like the Great Lakes in the Midwest where you get a lot of cycles throughout the course of the winter.

MR. POPOVICS: Or here.

MR. JONES: Or here. The mid-Atlantic. There's this issue of micro-diffusion, pore size distribution versus saturation.

So as freezing is going on it's a fairly complicated -- mechanisms are going on. You know, moisture is maybe moving around a little bit in response to the stress gradients and things like that.

Below some saturation threshold, you know, that this doesn't happen. Above which we start to see it.

Yunping I think brought up this notion of differential coefficient thermal expansion. So, you know, for differing moisture levels you'll have a, you know, stress getting induced by this effect.

And we talked about it a few slides back, but this, I'm going to my questions now, but there appears to be some integration with salt scaling. These two are similar, they're cousins maybe. Maybe brothers.

But not the same, from what we talked about earlier. Am I accurately characterizing that? I see some heads nodding.

MR. CHOWDHURY: This is primarily mechanical effect. Depends on other parameters of the mechanical structure of the concrete.

MR. BERKE: This can significantly affect the structural capability of the concrete. The concrete just basically loses all its strength.

MR. CHOWDHURY: Yes.

MR. POPOVICS: But by mechanical effect you mean the process of the degradation?

MR. CHOWDHURY: That's right.

MR. BERKE: Yes. Yes.

(Simultaneously speaking)

MR. POPOVICS: It's not chemical.

MR. CHOWDHURY: No, it's not chemical.

MR. BERKE: No, this is not chemical. This is totally mechanical.

MR. CHOWDHURY: Yes, all mechanical.

MR. BERKE: And this goes back to how they were testing freeze/thaw many years ago. They used to freeze in air and thaw in water. That's a much more mild test.

MR. JONES: Yes.

MR. BERKE: Than freezing in water and thawing in water, which is done today. But the advent of the so called freeze/thaw testing, where people freeze and thaw in water.

But the old machines used to thaw with the use of freeze in air and thaw in water. You can get 300 cycles on one of those and not get past a hundred in the current Method A method.

MR. JONES: And so that's related to the saturation issue I assume?

MR. BERKE: Right.

MR. JONES: Yes. So that leads us into our sort of second generic question here. What concrete parameters influence freeze/thaw?

We know from the ACI design method that you put a little bit of air into the mix to --

MR. BERKE: Yes, for your strength.

MR. JONES: -- effect, you know.

I'm trying to prevent this, but I guess what are the key concrete parameters that get us into trouble here?

MR. BERKE: Well you need strength. You need a minimum strength to pass. Ideally ACI will tell you your water to cement ratio is going to be above 0.4 or 0.5.

But 0.50 will do okay. And you should have the right air-entrainment, which is based on the size aggregate you have. So there's a table for that.

And then the other thing that you don't talk about much, because most of the time it's not a problem, but your aggregate itself can be freeze/thaw susceptible. So you have to make sure you use an aggregate that is sound. Totally --

MR. JONES: Is that getting the porosity of the aggregate I guess or --

MR. BERKE: Yes, I think it's related to porosity in the type of --

MR. POPOVICS: It's the microstructure of the aggregate.

MR. BERKE: Some aggregates will hold water.

MR. POPOVICS: The worse possible pore structure.

MR. BERKE: And I've run into that in actual experience where we've gone in a different part of the quarry and an aggregate's perfectly okay. Turned out that everything was fed in freeze/thaw. And we found out that the DOT took it off its approved list because the section of the quarry where they're at.

MR. JONES: So it happens.

MR. POPOVICS: Some people argue that you can -- there's no defense ultimately against freezing and thawing that you can make any material, under the right conditions, have this damage. But, you know, proper design and proper air-entrainment, in some cases, that's the usual way to do it.

But there are cases where you have extremely dense strong concrete that does not have any air-entrainment and it doesn't suffer freeze/thaw --

MR. BERKE: Yes, but that's not our case here.

MR. POPOVICS: No. But I mean my point is --

MR. BERKE: That will solve a lot of problems if they don't occur in that kind of concrete.

MR. POPOVICS: But saturation is pretty much everything. If you fully saturate the pore structure, you know, it's hard to let the material survive for very long.

MR. BERKE: Yes. And that's why vertical surfaces do much better. It's very hard to saturate vertical surface. Especially if you got a heat source on the other side that's trying to suck the moisture out.

So it's really almost always seen on horizontal surfaces. Or some surfaces, if you're buried in soil with water and you're above the -- everything in the soil is above the -- you're above the frost line, you can go up and down with freezing. With the surface.

Those are the places you're going to see it. Ocean where you have the waves will come in and get it wet, it will freeze. Then the way the water will come in and thaw it out. So the water will also -- so tide is always very bad.

But it has to be someplace where the concrete is saturated.

MR. POPOVICS: Saturation is really bad.

MR. CHOWDHURY: Yes.

MR. BERKE: When the concretes dry, you're not going to, in most cases, you're not going to induce thawing. I won't say it will never happen, but if it's dry it's unlikely.

MR. CHOWDHURY: So a lot of similarity between salt scaling and this one.

MR. BERKE: Yes. Well --

MR. POPOVICS: That requires freezing and --

MR. BERKE: -- they both require freezing --

MR. POPOVICS: -- moisture.

MR. CHOWDHURY: Yes.

MR. BERKE: And saturation. But I mean, water is saturated.

But you can get, as mentioned earlier, you can get scaling without getting freeze/thaw. If you get freeze/thaw you're probably going to have a scaling problem.

If nothing else the freeze/thaw, when it's severe, will cause scaling on its own. Without the salt.

MR. JONES: You know, it points up another thing. Construction practice is very important.

MR. BERKE: Yes.

MR. JONES: So if you have poor construction practice, poor finishing, you can promote this kind of surface damage.

MR. BERKE: Absolutely.

MR. JONES: Because you have a surface layer, a poor layer at the surface, that can be avoided by proper practice.

MR. BERKE: It's also when you place the concrete. I mean if you can place concrete, like in the end of the, normally you're not going -- in this type of weather or like the end of the fall, and it's still saturated from all the water that's there and goes through freeze/thaw cycles then, you can't develop any strength.

and the concrete meet. And that's the kind of stuff that we primarily are looking at. We also have them down below on the inlets. They come off of the corners of the inlets as well.

MALE PARTICIPANT: Forty-five degrees.

MR. PLANTE: Yeah, about at a 45 degree angle, exactly right. So I just wanted to bring that up to the group. Thank you.

MS. RAY: Thank you. Are there participants on the phone that would have additional comments?

MS. GILMORE: Well this is, if nobody else does, it's Donna Gilmore again.

MS. RAY: Go ahead.

MS. GILMORE: Okay. So it appears that, because of the situation of the interior being hotter, that we could potentially have these cracking or delaminating conditions sooner than other situations because of the different mechanisms that were described in this meeting. Did I understand that correctly?

MR. JONES: Yeah. I don't know that we implied that that would be sooner. Or I certainly didn't get that --

MS. GILMORE: Well, that's why I'm asking.

I'm asking a question. Would it, at least theoretically, be sooner.

MR. JONES: Well, I guess I'm hung up on the notion of sooner. Sooner than what? Without a heat load, is that what you mean?

MS. GILMORE: Sooner than you're experiencing in other situations that have these problems happening.

MR. JONES: I don't know that we hear that conclusion, ma'am.

MALE PARTICIPANT: No.

MS. GILMORE: Well, I'm just kind of, so I guess what I'm trying to figure out is how soon could we have a serious problem in, you know, I know you mentioned that something could be replaced. But we have to pay for that. So, you know, so that's a money issue. And we don't have money set aside for this kind of long term maintenance.

So I'm just trying to get a handle on, you know, do we need to allow a lot more money here? We're right in the planning stages at San Onofre. So this is a big issue for us.

MS. RAY: Donna, is your concern on the inspection?

MS. GILMORE: So how soon would this might happen, is what I'm trying to get at, that we might need to do some kind of major repair or replacement? How early should we prepare for that as a potential, conservatively speaking?

MR. JONES: I think, unfortunately, that's the question that we don't know the answer to. If we did, it would make our lives a lot easier.

MR. POPOVICS: I think good inspection techniques are paramount to all degradation mechanisms, holistically. And really, that should --

MALE PARTICIPANT: First of all --

MS. GILMORE: It doesn't sound like you have one, the testing is just internal to the concrete and not visual on the outside.

MR. CSONTOS: Donna, you know, this is Al Csontos again, you know, we at NRC have to look at all the sites, all 50-plus sites around the country when it comes to this. And we have to make our regulations, you know, uniform for everyone, okay.

MS. GILMORE: Of course.

MR. CSONTOS: We can't go out and make a, you know, we, at this point, have to be thinking about what we can do. And that's what Aging Management

Programs are there for. And that's what ACI 349.3R does, is that we do this through an inspection and assessment of those degradation mechanisms that can challenge the performance of the canisters for its intended function.

And then we either repair, replace or mitigate them. But if we replace them, you know, that's fine too. I mean, you're right. It's an additional cost, but from NRC's point of view, we're worried about those safety functions, okay.

And if a licensee does not maintain their systems where the safety function is maintained, then they will have to replace them, or repair them or mitigate them. And so that's the whole strategy that we're doing here. And we don't have a date that we can give you, because we're looking at this holistically throughout the whole country.

MS. GILMORE: Well, I'm speaking holistically. I'm just, you know, I'm speaking holistically. How soon could this potentially happen in any location? I'm just looking for a conservative range. But if the answer is you don't know, then I'll take that.

MS. RAY: Donna, we have someone who would like to speak.

MR. SISLEY: Hi. My name is Steve Sisley. I'm with Energy Solutions, one of the certificate holders. I'd just like to say that the temperature gradients that we're talking about are a design load. We designed the cask systems with sufficient strength to withstand the highest temperature gradients that the systems can possibly take.

So this is not an aging related issue. This is a design condition that we designed for. And these systems are strong enough to take the maximum temperature gradients.

MS. RAY: Thank you. Donna, could you hold one moment. I'd like to see if there are other participants here in the room that would like to make comments.

MR. XI: Well, I'd like to make a comment about what you just said. So you're talking about thermal stress. So is thermal stress induced by the temperature readings?

MR. SISLEY: Yes, absolutely.

MR. XI: But we've been talking about the temperature gradient driving the moisture movement. So these are two different issues. I'm not saying the thermal stress is not important.

MR. SISLEY: Well, it sounded like the impression was that these systems weren't designed for the temperature loads. And I just wanted to address that. They are designed for these temperature loads.

MR. XI: Yes. From a mechanics point of view.

MR. SISLEY: Yes.

MR. XI: But not from a durability point of view.

MR. TORRES: Yeah. And I think that that's why we're having this discussion here, to identify that there are gaps that we need to potentially do further research or to entice further research, whatever is needed at this point with what we know those design basis limits are adequate and this is our approach. But again, we rely on inspection and monitoring to make sure that that --

MR. CSONTOS: Right. And, Donna, this is Al again. The reason why we're hedging on your answer is because it's so complex, okay. We're looking at various mechanisms, multiple different mechanisms, multiple different heat loads, multiple different locations around the country, multiple mobility paths for water ingress and other types of chemical reactions to occur.

I mean, that's a heck of a lot of things to try to nail down. And so instead, we are focusing on inspection and other inspection technologies to then assess what type of performance we can maintain over the period of the renewed operation for these systems.

So I hope that helps answer your question. Because we've really spent a lot of time on this one question. Is that okay? Are you still there, Donna?

MS. GILMORE: Well, yeah. Maybe if you can at least include in a summary some, you know, key issues that you still need to investigate.

MR. CSONTOS: Sure, okay. We'll do that.

MS. GILMORE: That might just clarify that. Okay, thank you.

MS. RAY: Thank you, Donna. And your comments have been put on the record. So we do appreciate that.

MS. GILMORE: Okay, thank you.

MS. RAY: Are there other participants on the phone that have comments?

MR. HOFFMAN: This is Ace Hoffman.

MS. RAY: Could you repeat your name one

more time, sir?

MR. HOFFMAN: Ace Hoffman.

MS. RAY: Okay. Please go ahead. Thank you.

MR. HOFFMAN: Two quick points. First of all, in reference to what Donna was saying and Csontos' answer, you have to investigate the worst cases and cover all cases. Because you're trying to write a generic proposal or a generic regulation. So I just wanted to mention that.

And the other thing is, earlier somebody mentioned that all decay mechanisms rely on moisture. And so I'm wondering what are the chances that the NRC is going to recommend that these dry cask storage locations all be enclosed in an airtight building to reduce the moisture significantly and also reduce the salts and all the other things.

It just sounds like that's the first line of defense. And we've always had a lot of levels of defense in the nuclear industry, at least we've been told we have those in here in the dry cask storage system. We have one at most. And so perhaps we need more. Thank you. Those are my --

MS. RAY: Thank you. Is there anyone from the staff who would like to respond?

MR. CSONTOS: Ace, thank you so much for those comments. We'll take them, you know, under advisement. But that's, at this point, we can't, you know, there are other mechanisms that may not require moisture. That's a radiation induced type of issue. So those are things that we also look at. But your points are well taken. Thank you, Ace.

MS. RAY: Ace, did you have any other comments?

MR. HOFFMAN: No, thank you.

MS. RAY: Thank you. Folks in the room, any comments?

MR. WALL: My name is Joe Wall. And I'm from EPRI. And I just wanted to point out that we have over 40 years of operating experience with biological shields which have similar heat loads that dry cask storage does. And we haven't seen any accelerated aging in the bioshields.

MS. RAY: Thank you for your comment. Other participants on the phone, do you have any --

MR. DUNCAN: Yeah. Andy Duncan from Savannah River.

MS. RAY: Yes, go ahead.

MR. DUNCAN: In combined aging mechanisms one needs to balance, I think, environment to minimize both the effects of maybe corrosion and carbonation.

I know that in intermediate relative humidities, the carbonation rate peaks out and is much higher than if it's very wet or very dry. So it wouldn't necessarily be the best thing to put all these cask storage facilities in an interior humidity controlled environment, say around 45 percent relative humidity, because that's when the carbonation rate is the highest.

So if you, 200 years from now, if you end up getting a leak and the moisture goes higher, now you've got carbonated concrete and no protective barrier between your rebar and your surface.

MS. RAY: Thank you. Did you have any other comments to add?

MR. DUNCAN: No, that's fine. If somebody else wants to disagree or has an educated comment, I'd appreciate listening.

MS. RAY: Any follow-up comments for this?

MR. TRIPATHI: Well, I think we agree with, in general, we agree with what you just said. But right now, we are not aware of any licensee has any plans to enclose the storage units either vertical or horizontal.

But your point's well taken.

MS. RAY: Thank you. Are there other comments from people in the audience here? Yes?

MR. LOMBARD: This is Mark Lombard. I'm the director of the Division of Spent Fuel Management here at the NRC. And I'm hearing some of the comments from Donna Gilmore and Ace Hoffman.

This is the first time we have engaged an expert panel on concrete. And the reason is that we want to make sure we start to gather that information that would eventually flow into a regulatory framework.

Now, as it flows into a regulatory framework, as Mr. Hoffman brought up a good point, that the regulations are generic, I guess, for lack of a better term. They're the same for everyone.

But the Aging Management Programs, and the title of an aging analysis really starts first in the Aging Management Program, is very specific to a specific dry cask storage system at a specific site.

And if there are issues that we identify that are specific potential degradation mechanisms for a site in a dry cask storage system, certainly the Aging Management Program that we would approve for that system would include inspections and, as Al said, mitigation or replacement techniques for that degradation mechanism.

So we're just kind of starting this effort. This really applies to the second renewal period, at least time equals 60 years of dry cask storage.

And so a lot of your questions seem to indicate that you may be thinking that this is going to flow into requirements immediately. But we're some time away from actually changing either requirements or Aging Management Program requirements.

But I will say that if we identify a safety issue, a potential safety issue at any time during this process, clearly we would go after that safety issue if it is probable that that would apply to, again, a specific system sitting on the ground now at a specific site.

MS. RAY: Thank you. Other participants? Oh, yes? Go ahead.

MR. JUNG: I'm Andy Jung from Areva. I'm not an expert for concrete. But I'm working for corrosion of the metals.

One question is we're supposed to inspect both, like, interior and exterior surfaces on the concrete overpack. Or only we are supposed to go only inspect outside of concrete. Because the, again, I'm not an expert for this concrete degradation.

But if we, like, most likely more benign condition of inside of concrete except for, like, some additional, some radial issues affects can make the moisture some disassociation.

Other than that if, like, inside it's more benign condition, we can maybe go only outside exterior inspection rather than both sides. Because, you know, it is so difficult to go to inside for concrete degradation.

MS. RAY: Is there anyone from the staff who would like to follow-up on this?

MR. TORRES: Yes. At this point, in the Aging Management Program, for the first license renewal period includes inspections of the interior and exterior.

And the justification for doing inspections of the interior, again, is we need operating experience. We want to know how the systems look inside to be able to then have a justification to say systems can only be inspected from the outside.

MR. JACOBS: But, Andy, when you said interior, did you mean embedded, embedded concrete, embedded steel?

MR. JUNG: No. So inside all that.

MR. JACOBS: Okay, all right.

MS. RAY: Please use the microphones.

MALE PARTICIPANT: Exterior overpack.

MS. RAY: Thank you.

MR. TRIPATHI: Let me add to what Ricardo just said. That inspection involves inspection inside or outside, doesn't matter where, anything which affects the functionality of that dry storage cask.

Not just structural, but there are other disciplines which are also affected, shielding, criticality, containment, thermal, what have you. So anything which affects the functionality of that life of the cask or whatever the licensing life is, it's included in the inspection, inside, outside, doesn't matter.

MS. RAY: Thank you for that clarification. Are there other participants on the phone that would like to make a comment?

MS. GILMORE: This is Donna again. I have a quick question for the EPRI person. He mentioned that they have examples of a similar heat load. Could you identify what that is?

MS. RAY: Donna, if you would please, we're taking questions directed to the staff at this time.

MS. GILMORE: Oh, okay. Okay.

MS. RAY: Other participants on the phone that would like to make a comment? Anyone in the room that would like to make any further comments?

(No audible response)

MS. RAY: One last time, anyone on the phone?

(Off microphone discussion)

MR. CSONTOS: Correct me if I'm wrong. This is Al. It was the bioshields, right?

MR. WALL: Yeah.

MR. CSONTOS: In reactors.

MR. WALL: The entire reactor cavities.

MR. CSONTOS: The reactor cavity that surrounds the pressure vessel --

MR. WALL: That's correct.

MR. CSONTOS: -- that has a very large heat load. Because it's actually creating the energy. It's not boiling, but it's very hot. And so that sees the temperature range that you're talking about, Donna. So that's why, you know, I just wanted to make sure we clarified that so you'd have that statement out there.

MS. GILMORE: Thank you.

MR. CSONTOS: Oh, and inside the container.

MS. RAY: Yeah, one more time, anyone in the audience that would like to make a comment?

(No audible response)

MS. RAY: And is there anyone on the phone that has additional comments?

(No audible response)

MS. RAY: There will be additional comment period tomorrow, in case you have burning questions in the evening. But I will turn it back to Chris for concluding.

MR. JONES: Great, thanks. So this pretty well wraps up the first day of our expert panel. We, again, say thanks for the time to come out here and visit with us about these concrete degradation issues.

We, I think, have covered a lot of interesting things. And I think tomorrow is really where we begin to transition into how to act on some of these things with the inspection and monitoring, Aging Management Programs, TLAAs, repair and remediation, et cetera. So, you know, I look forward to that.

I think, you know, frankly we've wrapped up a little bit ahead of schedule which is, you know, great for everyone. So we'll look forward to seeing everyone back at about 8:30 tomorrow morning. And we'll proceed from there. So thanks, everyone.

MALE PARTICIPANT: Thanks, Chris.

(Whereupon, the above-entitled matter went off the record at 4:10 p.m.)