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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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MATERIALS, METALLURGY AND REACTOR FUELS SUBCOMMITTEE

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WEDNESDAY

MAY 22, 2013

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ROCKVILLE, MARYLAND

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The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 1:00 a.m., J. Sam Armijo, Chairman, presiding.

SUBCOMMITTEE MEMBERS:

J. SAM ARMIJO, Chairman

MICHAEL T. RYAN, Member

STEPHEN P. SCHULTZ, Member

WILLIAM J. SHACK, Member

GORDON R. SKILLMAN, Member

NRC STAFF PRESENT:

CHRISTOPHER L. BROWN, Designated Federal Official

AL CSONTOS, RES/DE/CIB

ROBERT EINZIGER, NMSS/DSFST

HIPOLITO GONZALEZ, NMSS/SFAS

PATRICK RAYNAUD, RES/DSA/FSCB

JIM RUBENSTONE, NMSS/SFAS

HAROLD SCOTT, RES/DSA/FSCB

DAVID TANG, NMSS/DSFST

BOB TRIPATHI, NMSS/DSFST

ALSO PRESENT:

JOHN KESSLER, EPRI*

*Participating via telephone

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P-R-O-C-E-E-D-I-N-G-S

12:59 p.m.

CHAIR ARMIJO: All right, let's come to order. Good morning, the meeting will now come to order. This is a meeting of the Materials, Metallurgy & Reactor Fuels Subcommittee.

I'm Sam Armijo, Chairman. ACRS members in attendance are Steve Schultz, Bill Shack, Mike Ryan and Dick Skillman. Christopher Brown of the ACRS staff is the Designated Federal Official at this meeting.

The purpose of the meeting is to receive briefing from the NMSS staff on ISG-24 Revision 0, the use of demonstration programs as confirmation of integrity for continued storage of high burnup fuel beyond 20 years.

The Subcommittee will gather information, analyze relevant issues, facts, and formulate proposed position and actions as appropriate for deliberation by the Full Committee.

The rules for participation in today's meeting were announced as part of the notice of this meeting, previously published in the Federal Register on May 17, 2013.

I've been told that industry representatives will be on the phone lines, and at the end of the meeting we will open up the bridge line to receive any comments.

Participants should first identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

Please silence all phones at this time.

We will now proceed with the meeting, and I call upon Bob Einziger, of the NMSS Spent Fuel organization to begin.

MR. EINZIGER: Thank you, Mr. Chairman.

When I originally prepared this talk, I was going to talk just about ISG-24, and was asked to also start out by talking a little bit about high-burnup fuel, what it is, what it does, what our concerns are about it, sort of setting the stage for ISG-24.

In the 2003 time frame, NRC issued some guidance for applicants, and for the staff, and they are going to evaluate applications for storage and transportation on what they could use as acceptable limits to try and guarantee that the fuel was going to behave like it was expected to behave.

That guidance, ISG-11, Rev 3, the third in a series, established a maximum storage temperature of 400 degrees C, and it was for all zirconium-based cladding types.

Now, the basis that went into establishing these limits were, they wanted to prevent cladding creep from exceeding 1 percent. They thought by establishing this temperature limit that they were going to prevent any hydride reorientation from occurring, and they expected that they would not have any cladding corrosion issues when the task was sufficiently and acceptably driving backfill with helium.

Under these guidelines, the fuel was stored. They did a confirmation test in the, oh, the 2002 summer timeframe, where they, actually, opened the cask of high-burnup -- excuse me, low-burnup fuel that was out in Idaho. This wasn't originally intended as a demonstration, but they had loaded some casks up with fuel to benchmark codes. And so, there was some data that was taken on the pre-characteristics of the fuel that was available and some that wasn't.

Anyway, they opened up this cask, and they looked at the fuel. They got the fuel, they examined it visually. They did some destructive examination, and, lo and behold, the fuel was pretty much just like they put it in. And, everybody had a good confident feeling that the kinds of predictions they were making, based on the short-term tests that were the support for ISG-11, in fact, were holding up. They weren't seeing anything unusual and unexpected. There was a little bit of crud spallation, but there was no failed rods, there was no excessive creep, no corrosion, and so everybody felt good.

And, when people were looking for moving on to license extension for low-burnup fuel, the question would come that they may have stored it for 20 years and you are looking for a longer extension, how do you know that the fuel in there is what you expect it to be, because the storage regulations say you have to know the condition of the fuel. And, basically, they would point back to this demonstration and say --

CHAIR ARMIJO: Bob, just a quick question.

Was that 15 years in storage?

MR. EINZIGER: Yes.

CHAIR ARMIJO: For that particular fuel.

MR. EINZIGER: Yes.

CHAIR ARMIJO: Okay. So, it was pretty close to the 20-year limit. I mean, it's --

MR. EINZIGER: Right.

CHAIR ARMIJO: So --

MR. EINZIGER: Plus, that fuel had also undergone a few excursions during the phase when it was a test program for a different issue.

And so, everybody felt comfortable. Yes, we have some evidence that based on our short-term predictions the fuel behaved like we said it was going to behave. We don't seem to be stressing any limits. The creep was next to nothing, so we are good to go on, so we'll grant them another 40 years. I think that's what it was. I'm not sure whether the licenses started to be granted just prior to or after we extended the storage period to 40 years.

In any case, at that time there's been a number of people at DOE, and NRC, and EPRI, that were making the case, well, you know, the burnups in this fuel are not sticking at 35 or 40, they are starting to get higher, and that maybe we should be starting a demonstration now, just to make sure that we don't get surprised.

One of the major concerns that was hydride precipitation, as you went to high-burnup fuel. This is a plot of the solvous and precipitous of hydrides in Zircaloy. You notice that there is a hysteresis, so as you start heating the fuel up during the drying process you, essentially, climb up the red line.

And so, if you go to the maximum temperature of about 400 degrees C, you have about 200 ppm of hydrogen in solution. Well now, as you start cooling this, you are going to go into a super saturated solution until you get down to about 330, at which time you are going to start precipitating hydrogen back out of solution as you cool down.

Now, the hydrogen that was formed in the reactor, that went into the cladding, you know, you oxidize the cladding, some of that hydrogen that's formed the oxidation process, somewhere between 12 and 20 percent goes into the cladding. And, it, generally, forms circumferential hydrides, due to the state of the stress in the cladding while it's in the reactor.

Well now in storage, the straight stress state is different, because you no longer have the back pressure of the cooling. So, as you start cooling it and precipitating the hydrides, some of these hydrides form in the radial direction.

And so, the question was, what conditions can we set for storage so we don't get the radial hydrides, and the secondary question, which later became the primary question, if you do get the hydrides precipitating in radial direction, is there any detrimental effect of it?

This is a picture, two pictures, in fact, of ZIRLO, with a picture showing on how it came out of the reactor. You will see it's mostly circumferential hydrides, with a fairly dense hydride layer near the surface of the outer surface of the cladding. Now, if you undergo a hydride reorientation test that might be typical of what you see in a drying process, where you bring it up to 400 degrees C, and then you start cooling it slowly, and we cooled it at 5 degrees C per hour. The reason that this was picked instead of 1 degree per hour, or much lower, is that there is some finite experimental constraints you have to do these tests in a reasonable amount of time.

Now, the picture that you see on the right, I'm never sure when they say picture on the right, is it from their view or my view.

CHAIR ARMIJO: Our right.

MR. EINZIGER: In any case, that's after a sample had cooled down with a decreasing stress. In other words, it was 135 megapascal stress when the cladding was at 400 degrees C, and it had a mandril in it, and as it cooled down the stress dropped, both because the temperature was dropping and because the pressure was dropping because of the stress.

CHAIR ARMIJO: Was this a gas pressure?

MR. EINZIGER: Yes.

CHAIR ARMIJO: Creating the stress.

MR. EINZIGER: Yes.

CHAIR ARMIJO: Okay. And, is the sample,

the picture on the right, the same material as the one on the left, that same fuel cladding would do that same thing?

MR. EINZIGER: These were both ZIRLO.

CHAIR ARMIJO: These were both ZIRLO, with the same irradiation history?

MR. EINZIGER: Similar.

CHAIR ARMIJO: Similar. Okay. Close enough.

MR. EINZIGER: These were just being used -- it's not to say that becomes -- that sample became this, it's to show, in general, this is what you get out of the reactor --

CHAIR ARMIJO: Right.

MR. EINZIGER: -- after you go through hydride reorientation tests, you'll get something like this.

CHAIR ARMIJO: Okay.

MR. EINZIGER: They are not the same sample.

CHAIR ARMIJO: No, I just wanted to know if it was the same batch, and the same kind of burnup, and the same kind of --

MR. EINZIGER: I'd be remiss in telling you yes. I can just tell you that one is after testing and one is before a test.

Obviously, this is in the 500 ppm hydrogen, this is only in the 190 ppm hydrogen case.

What you'll notice is radial hydrides. Actually, this is one of the better radial hydride cases, because you see a number of circumferential hydrides still sitting in there that are breaking them up.

Many times, if the hydride level is just right, you'll just get hydrides that are going straight through. So, the question becomes, what happens, why does this happen, and what controls that it happens, and what's the effect of it happening?

Well, to try to come up with a model of this is a very difficult thing. We know a couple things. If you don't make your unirradiated sample correctly, if you want to try to do this on unirradiated material by charging with hydrogen, unless you get the morphology of the hydrides right, you are not going to be able to duplicate a similar effect with irradiated samples.

We did a lot of work with unirradiated samples, and then said, okay, this is the region where we shouldn't have a problem, and, boy, we had a problem.

We know that the way the hydride develops is going to depend on the material conditions, it's going to depend on the cooling rate, the irradiation level, the hydride level, the rod stress. There's a lot of parameters.

So, we decided that we are not going to tackle that per se. We went on and did some tests, and we came up with some results in the Journal of Nuclear Material that, basically, says there doesn't appear to be any minimum stress under which you don't get radial hydrides. Japanese got radial hydrides all the way down to 25 megapascals.

If you lower the temperature, eventually, you get to the point where you don't put enough hydrogen in solution, so that there's an issue. How low is that temperature? Well, the Japanese decided that they would go about and lower the maximum allowable temperature to 275 degrees C, where the solubility is much lower. I think it's down in about the 50 or 60 ppm range, and that's how they got rid of the problem.

So, that's, basically, the background of where we stand with our knowledge of spent fuel.

CHAIR ARMIJO: Bob, before you go on, on your slide 5 there, on the right-hand image, that shows both the radial and the actual --

MR. EINZIGER: Circumferential.

CHAIR ARMIJO: -- circumferential hydride, you mentioned that a mandril was used. Where was the mandril used?

MR. EINZIGER: The mandril was only -- did not put stress on the cladding, the mandril was only in there to limit the amount of gas in there, so that you got the right decrease of stress with temperature like you would see in a spent fuel rod.

It was just a hollow tube, any expansion of the rod would result in an increase in stress, depending upon --

CHAIR ARMIJO: So, the mandril was a surrogate for the fuel color.

MR. EINZIGER: Yes.

CHAIR ARMIJO: Got you, okay, I understand. Thank you.

MEMBER SKILLMAN: Bob, just to review the slide 2, as we talked about the initial setup for the conditions, and then the testing, the original conditions, which were listed as 400 degrees C for normal operation, all zirconium-based alloy types, were thought to prevent hydride reorientation.

When they did the testing of the moderately-burned fuel, they didn't see this, the radial hydrides after 15 years?

MR. EINZIGER: They --

MEMBER SKILLMAN: I presume they didn't do any testing at 400.

MR. EINZIGER: -- you've got a number of things going to that question.

When they started out, they plotted up all the data they had on situations where radial hydrides can form. In other words, samples that had hydrogen in them, that were brought up to temperature, and then they were cooled. These were all done on a number of different conditions. Most of them were under stresses, there were stress with time. In other words, a pressurized tube, and this constant gas pressure even as the temperature decreased.

A lot of it was done on unirradiated -- very little unirradiated --very little work was done on unirradiated fuel. Most of it was on irradiated material.

At that time, it tended to believe that if you stayed below 90 megapascal stress at temperature, in other words, the stress in the rod was not above 90 megapascals when it was at 400 degrees, that you could -- you probably wouldn't get hydride reorientation, at least on the metalographic studies. But, I think there might have only been three or four data points right there, and that's what started getting people thinking, you know, this may not be the case.

Now, when we looked at -- when we took this test where there was fuel in storage for 15 years, and it was examined metalographically radial hydrides were not seen in that case.

MEMBER SKILLMAN: Okay.

CHAIR ARMIJO: Now, Bob, I can see where the radial hydrides would have a detrimental effect, when you are putting stress perpendicular to the hydride plates.

MR. EINZIGER: Yes.

CHAIR ARMIJO: So, the pressurized fuel rod, let's say at low temperature, I would expect the maximum embrittlement to be manifested. But, in a fuel rod that's stored axially, or even horizontally in a cask for a long time, you really only have -- and even envisioning some accident drops, and things like that, you are going to have tensile loads, which means, what's going -- actual tensile loads on the rods. And, the hydrides are not oriented. So, that's parallel, the stresses are parallel to the hydrides or bending.

Have you done any experiments or measurements for material that's got radial hydrides that the amount of embrittlement is insensitive to the loading, how it's loaded, or it's very sensitive to how it's loaded, whether you can come up with some criteria that says this much hydride is okay, this much hydride is not okay, for the kind of loading we expect in stored fuel?

MR. EINZIGER: I'll try to answer that question very briefly, because it will be the subject of another hour's worth of talking.

CHAIR ARMIJO: There's always a good answer.

MR. EINZIGER: But, the point is that, as my colleague David Tang always points out to me, really, the only time that this is going to be an issue when you might have a side drop and the fuel gets into a pinched mode, it's not going to have -- pinching the rods is a collapse down on each other through a side drop.

CHAIR ARMIJO: I see that as bending, am I thinking of what you are saying?

MR. EINZIGER: One rod on top of another.

CHAIR ARMIJO: Okay.

MR. EINZIGER: David, would you like to comment?

MR. TANG: I'm David Tang, Acting Branch Chief of Mechanics and Materials, same division.

What Bob was talking about, the pinching, really, we talked about pinching mode, any immobilization of a cross section, a hollow cross section.

So, only under that condition that really hydrides take the fact and try to prorogate the cracks. So, that was what we mean by pinching mode.

CHAIR ARMIJO: Getting back -- you could get that same thing just by bending of a tube, it will tend to fold.

MR. TANG: Yes and no, but, see, we do have a pellet, or whatever formed within the tube.

CHAIR ARMIJO: Yes.

MR. TANG: So, the tendency to have that kind of, say, scenario, or configuration is subject to that kind of bending is very unlikely for one.

Secondly, I think that we do have some testing program --

MR. EINZIGER: Well, I was going to get into that next.

MR. TANG: Okay.

MR. EINZIGER: Because that's the second thing.

CHAIR ARMIJO: There is a mode where you might, in the case of an accident, would drop, or you might get a pinching where the radial hydrides would have their maximum influence.

MR. TANG: Right.

CHAIR ARMIJO: But, for other normal kind of --

MR. EINZIGER: No, I don't envision this being a problem if the gas was just standing there.

Now, remember the original part of our program we were going to look and see, is there a set of conditions you can set on a curve, because of the issues with that, then problems with the hot cells, et cetera, et cetera, et cetera, we switched the question and said, okay, what if it occurs, is there any problems with it.

And, we did a series of tests where we now work between 150C and 0, where we put this in a ring compression test, and looked at the strain curve to see whether we were getting fracture of it. And, what we found out is that, as you lower the temperature, eventually, you are going to get to a brittle state. You are going to go through a little brittle transition, and that this ductile-to-brittle transition, normally for material with just a circumferential hydride is down at room temperature. When you start putting radial hydrides in it, it's going to increase when that occurs, at our low it increased to 150 degrees C. And, it's very dependent on the material. It's very dependent on the stress it was under.

So, yes, there can be a problem if you get to this situation. The problem probably won't manifest itself in storage. Where it will manifest itself, if at all, is during transportation, especially if you are going to transport, at a temperature that's lower than the ductile-to-brittle transition temperature, which could be the case as we go into extended storage where the fuel is going to sit there for an extended period of time.

CHAIR ARMIJO: Okay. So, it would be -- you would expect a problem, or there may be a problem, is when you have a sufficient amount of radial hydrides, and there is an accident of some sort, or a drop, that could stress the cladding in a manner that's similar to what you get in a ring compression test.

MR. EINZIGER: Yes.

CHAIR ARMIJO: Okay.

MR. EINZIGER: And, the ring compression tests have limited travel, so that, you know, we can crush anything in a ring compression test if we bring it out. But, this had a limited travel, so that --

CHAIR ARMIJO: Was it the order of 1 percent, 2 percent, or was it --

MR. EINZIGER: I think we had 1.7 percent.

That was about the least we could control with the apparatus. That's getting all off into another topic that at a later date --

CHAIR ARMIJO: I'll get into that, because there's one thing I definitely want to do, for everybody to understand, is what really constitutes gross rupture, because that's what your regulation says you've got to protect yourself again, gross rupture.

And, I've had a hard time imagining how these radial hydrides, even in an accident that lead to more than maybe cracking of the cladding.

MR. EINZIGER: For gross ruptures, it is not defined in the regulation. The staff has developed guidance for defining gross rupture, and we define it right now as any defect in the cladding that will allow fuel to get out of the rod.

CHAIR ARMIJO: Fuel particles?

MR. EINZIGER: Fuel particles, right.

And, we did some gross calculations of how much fracture you get of pellets, and what that is and the equivalent size, and what kind of --

CHAIR ARMIJO: Is that a separate document that we could look at?

MR. EINZIGER: You can find those arguments in ISG-2, I think it is.

CHAIR ARMIJO: Okay.

MR. EINZIGER: Where gross rupture is defined.

CHAIR ARMIJO: That's pretty conservative, Bob, I think, at least to me.

MR. EINZIGER: Well --

CHAIR ARMIJO: ISG what?

MR. EINZIGER: ISG-2.

CHAIR ARMIJO: ISG-2.

MR. BROWN: I'll get it for you now, Sam. I know which one it is.

CHAIR ARMIJO: Yes, okay.

MR. EINZIGER: Yes, it is conservative, but we are a conservative organization.

And, in any case, that's one of the effects that goes on.

You've got to realize that there's a lot of effects that have been postulated for disruption of the fuel that we don't give a lot of credence to. Almost the whole world is looking at creep. We pretty much said creep isn't an issue, it's a self-limiting thing. The rates may be different from material to material, but so what, it just means you self-limit faster.

DOE is very interested in delayed hydride cracking, and it has a research program in that. Our position on that is, the stress you get from the gas is not enough, you just can't drive delayed hydride cracking. So, until you can show us a stress that's going to drive it, we are not going to fund the research to look at it.

There was a mechanism on habitation growth that was similar we dismissed.

CHAIR ARMIJO: So, this is the one remaining one that you think has a chance of really affecting.

MR. EINZIGER: It may have the effect, and, unfortunately, Sam, I'm not a very good seer, so there's always the chance no matter how many things I think could happen, something else could turn up that I hadn't thought about. And so, we like to at least test some material under typical conditions to make sure that we don't get surprised.

CHAIR ARMIJO: Okay.

MR. EINZIGER: So, why high-burnup fuel? Well, there's a few differences between high and low-burnup fuel, and we've defined high-burnup fuel as greater than 45 gigawatt days per metric ton, and that doesn't mean that at 44.4 you low burn, up to 44.6 you -- or 45.6 you high-burnup.

It's defined as 45, because that's when many of the properties of spent fuel start to change from a fairly linear behavior to more of an exponential behavior and increase significantly.

You are going to form a rim region in the pellet that has very fine grain, very high pressure bubbles in it. We don't know how that rim is going to be behaving, with respect to increased storage.

You are going to have much greater fission gas release, while it might be only 1 or 2 perfect for most rods in low-burnup. You get to a high-burnup you may be talking 6 to 8 percent fission gas release. You have a thicker oxide layer, because you've been in the reactor corroding longer. You have a higher stress because of the higher fission gas release and the thinner cladding. And, you also have a lot more hydrogen going into the cladding, while you might only be in 100 ppm or so down in low-burnup fuel, for high-burnup fuel, depending on the cladding, you could be up to 500, 600, 700 ppm. So, there's a number of differences.

CHAIR ARMIJO: Well, Bob, that's something that does puzzle me, is that if you do corrosion and hydrogen pick-up, generally influence is, basically, exposure time on burnup. So, if you take the fuel assembly, you take it out to 45,000 megawatt days per ton, and, say, two-year cycles, you've got four years of exposure and temperature in that reactor.

But, if you load more enrichment, and design the fuel road differently, you'll get to the 60,000 megawatt days per ton, but the exposure time is the same. The fluence is the same.

Now, the stress inside, because it's gas produced and all that, I agree, is different. So, how do we --

MR. EINZIGER: We can only talk in generalities, Sam.

There's not a good correlation between the oxide thickness and the hydrogen or the hydrogen pick-up, it just isn't there. In fact, if you go into one rod that's been in the reactor, and you take a cross section of it and you measure the oxide thickness around the cross section of it, you could get almost a factor of two, sometimes difference in the oxide layer thickness.

So, it's not a well-established fact of what's going on.

CHAIR ARMIJO: Yes, well, Bob, you could put my question to bay, just if you had data that says, look, we agree, exposure time is important in both fluence and corrosion, and hydrogen pick-up, but the fact of the matter is, we've measured the hydrogen pick-up and corrosion, and high-burnup cladding and low-burnup cladding with the same exposure times, and they are different.

You point me in that direction, and I'll puzzle about it. You know, if that's true, then burnup is the right thing to worry about. But, if it isn't true, if it's just exposure time --

MR. EINZIGER: I don't think it's just exposure time, because pick-up rates are changing, and there's a lot of things.

CHAIR ARMIJO: Okay. Well, just keep thinking about that some more.

MR. EINZIGER: Well, we are always prodding the fuel manufacturers for more data on oxide thicknesses, oxide morphologies, hydrogen pick-up, hydrogen amounts and morphology, so we can try to make a more complete picture of what's going on.

CHAIR ARMIJO: Yes. Well, if they were here, I'd ask -- I'd be asking them the same questions, you know, what's really controlling the risk to this material, is it really the fact you've got it in the reactor longer, or that you truly have higher burnup of the fuel. Okay.

MR. EINZIGER: Did you want to say something?

MR. RAYNAUD: This is Patrick Raynaud, from the Office of Research.

CHAIR ARMIJO: Yes.

MR. RAYNAUD: One thing that also will have an impact on corrosion and hydrogen is the texture of the fuel rod. Even if it's the reactor for the same amount of time, if it achieved a higher burnup it would burn even hotter. And, you might have closed your gap earlier also, and so you are going to have maybe a higher cladding temperature, so you accumulate more oxidation, and, thus, more hydrogen, even though you are in the reactor for the same amount of time.

CHAIR ARMIJO: I don't know how you get the cladding hotter, but I'll think about that.

But, there's no question that you'll get higher stress, because you've got more fission gas. So, I'm just still wondering about how you, actually, get higher hydrogen pick-up. Is it a function of burnup as opposed to a function of time.

MR. EINZIGER: I wish I had a good story on hydrogen pick-up.

CHAIR ARMIJO: I wish I had some solid data.

MR. EINZIGER: I can't even explain why if you take one rod and you do a cross section, the hydrogen on one side of the rod, and the hydrogen on the other side of the cladding will be different, but they are.

CHAIR ARMIJO: Okay.

MR. EINZIGER: I'd like to move a little bit at this point into, really, the purpose of this, and that's to talk about the ISG-24.

I want to preface that by stating that we do not believe that there is a problem in the storage, that all hell is breaking loose. Otherwise, if we believed that, we would have never licensed it to get in there in the first place.

But, the database under which the assumptions were made that drove the models is a very limited database, taken under a short amount of time. There are differences between high-burnup fuel and low-burnup fuel. And so, it would be nice to get a check on what's going on, and, really, make sure that, one, that what we thought was going on is really what's going on, that we are not getting new mechanisms inactive that we didn't think that are active.

I mean, I used to live up in New Jersey for 20 years, now I'm down here. I know the route between here and New Jersey, but every once in a while I still pick up my map to make sure I'm in the right place, and that's about what we are doing here, is we are taking out the map just to make sure we haven't strayed for some reason or another.

We are having a lot of license applications now for storage renewal, a lot of them have high-burnup fuel in them. We have applications in for transportation licenses to transport high-burnup fuel. And, all we are saying is that, okay, you've got the go ahead for 20 years, we think we are good for 20 years, but before we are going to give you a license extension beyond that 20 years we want you to give us some information that says, yes, this is what we thought it is, and this is what we are seeing.

Now, there's a number of ways to do that. One way is, you've got a 16, 20, 30 cask, open one up, show us the fuel. Another way might be, if you are going to start new and you want to anticipate down the road, put a lid on the things that you can monitor that fuel all the time. Another way might be, well, it could be a demonstration somewhere, where they will take fuel, and they will put it in, under a set of normal conditions, and they will see whether the stuff behaves okay. And, if it looks like it's doing okay, it's not pressing the limits, okay, there's some evidence, you get a good warm fuzzy feeling that everything is okay.

And so, that's a number of options of way that you can approach the problem.

And, the purpose of this ISG is to give guidance to the reviewer of an application, should a renewal application comes in, and want to say, listen, I know what the condition the fuel is, everything is fine, and the basis for this is this demonstration program. It's the guidance to that reviewer to what he should look for in that demonstration program, to make sure that that data that's coming out, and the conclusions coming out with, are adequate for making a determination.

I mean, let's face it, I remember when I was in EBR 2 and the way they used to take some of those fuel rods and get rid of them, is they threw them out -- put them in a pipe and throw it out on the old back 40.

Well, that's not going to be a demonstration, that's going to give us a lot of data. And so, if somebody quoted data like that, well, no, that's not a demonstration that's adequate.

And so, the purpose of this ISG is that, if someone chooses to use a demonstration as a means of showing that the interior of the canister is good, that this is what the reviewer should look for.

It also gives us some information, you know, part of ISG-11 was predicated on the fact that the canister was dry, and was backfilled with helium, but you know we never opened the canister up that's been, actually, dried into prototypic conditions, and, actually, seen whether the water, actually, got out of there.

Now, I'm going to ask you --

CHAIR ARMIJO: Quite an oversight.

MR. EINZIGER: -- now, Sam, I'm going to ask you a question.

CHAIR ARMIJO: If there were just a little bit there, I would think in time it would be reactored and everything would be fine.

MR. EINZIGER: Well, we have --

CHAIR ARMIJO: If you are putting a couple gallons in there, I'm not sure that's a good idea.

MR. EINZIGER: -- well, I don't know whether we are leaving anything in there.

CHAIR ARMIJO: Yes.

MR. EINZIGER: But, you know, if you add up all the space in the dash pots of a large gas with BWR fuel, it's like 25 gallons in those dash pots.

CHAIR ARMIJO: The dash pots aren't monitored.

MR. EINZIGER: The control rod has a sealed bottom with a hole, and there's water in the bottom so when the control rods drop --

CHAIR ARMIJO: Okay.

MR. EINZIGER: -- there's some bounce on them.

CHAIR ARMIJO: See, BWRs don't have that.

MR. EINZIGER: No. No. BWRs have their own issues with places to trap water.

CHAIR ARMIJO: Well, we have water rods with holes in them.

MR. EINZIGER: There's a document coming out very shortly that will describe potential traps in BWR fuel.

CHAIR ARMIJO: Okay. So, right now, you've got a question about water, residual water.

MR. EINZIGER: Yes, and from your own point of view, imagine how things would change if this thing isn't dry. Now the issues that we've eliminated, you know, amount of gas and other things. In any case, that's one thing that can be tested with this.

Another thing that can be tested is the -- is the predictive models that are used for temperature. So, there's a number of reasons for doing this, for somebody to do this demonstration should they choose, and we just want to make sure the reviewer knows what to look for, because reviewers are going to change.

CHAIR ARMIJO: But, Bob, this is research, if you choose to license using a demonstration from you, this is a way we could find acceptance.

MR. EINZIGER: Yes.

CHAIR ARMIJO: It should be easy to find.

MR. EINZIGER: Yes.

CHAIR ARMIJO: Okay. And, that's okay. I mean, I don't have a problem with that, because that says what your expectations are.

MR. EINZIGER: That's right.

CHAIR ARMIJO: If somebody wants to do it that way, that's the way they should do it. But, they still could come in with another approach that says, here's how we think you meet your ultimate requirement of avoiding gross rupture in the event of a --

MR. EINZIGER: That's a standard thing with interim staff guidances, any of the interim staff guidances.

CHAIR ARMIJO: Right.

MR. EINZIGER: They expound a position that the staff has analyzed and feels comfortable with. And, if an applicant wants to use that method, then they have a lot less work. If they just choose to use another method, they are free to use that other method, but then the complete onus of showing the other method answers the questions up to that.

CHAIR ARMIJO: Yes.

MR. EINZIGER: So, this is -- if somebody comes in with a demonstration, this is what the reviewer should look for, and these are the various reasons that a demonstration might be good.

CHAIR ARMIJO: Okay, I understand.

MR. EINZIGER: Now, what are the criteria that we are setting out for a demonstration? Well, the burnup of the fuel in the demonstration is to bound the burnup of the fuel that's going to be in the actual application. That's not to say if they want to use fuel that's burnt to 62 and the demo only went to 60, we are going to say, no, there's leeway there. But, it can't be, if they want to go to 62 that they are going to do a demonstration at 51. There's differences. They've got to be within a respectable region. It's got to be the same type cladding as in the application.

CHAIR ARMIJO: That gave me problems, Bob, in reading the ISG, is we have so many different types of cladding, there's two, there's four, ZIRLO, improved ZIRLO, M5, and who knows what else is coming down the pike.

And, these are pretty expensive, long -- very long-term activities in the demonstration of the program. So, you know, just how narrow with this does the reviewer look at cladding type. If somebody says, gee, I did it for ZIRC 2, and we think it applies to ZIRC 4, do you say no, it's not the same cladding type. or we did it for ZIRLO and we think it applies for new improved ZIRLO. I would hope that the staff would be looking for something that would be generally applicable. Just how broad is your position of cladding type?

MR. EINZIGER: Well, from the information we have on the performance of the fuel in the reactor, and some of the tests we did, we know that ZIRC 4 behaves differently, and M5 relates differently to 0. So, there's three classes right now.

We have -- I have no personal data on how much it's going to be sensitized to the sub-nuances of ZIRLO. We know that ZIRC 2 with lining behaves differently than ZIRC 4. So, one would have to make an argument on that.

CHAIR ARMIJO: See, it seems to me there has to be some sort of a supplementary thing, not, necessarily, part of that. Because in a demonstration, if you can't put every type of fuel in, then --

MR. EINZIGER: We've tried that in fuel development, it doesn't work.

CHAIR ARMIJO: Yes, so these are like 10, 15 year activities.

MR. EINZIGER: Yes.

CHAIR ARMIJO: So, you've got to make sure that after it's all done your cask supplier that it applies to as many of the types of fuel that are out there. Right?

MR. EINZIGER: Well, I mean, obviously, Sam, I mean --

CHAIR ARMIJO: I'm just trying to get --

MR. EINZIGER: -- if we had unlimited money, and unlimited time, and unlimited resources, we'd set up a multiple cask situation with lots of cladding, and that's not practical. Maybe not even necessary.

CHAIR ARMIJO: I think you are getting to my question, Bob, is that, you know, we agree, it's not practical to do it for every type of fuel clad, so then how do you solve this problem doing one demonstration for one, let's say, maybe a couple of different types of cladding happen to be in that cask.

And so, you say, hey, we finished it up, everything turned out fine, but, you know, now we have other claddings that have to be supported, how do you solve that problem of the cladding?

MR. EINZIGER: Well, part of the purpose

of a demonstration, what we would look to is how well the short-term data that was used in developing the anticipated behavior of the cladding is justified for use in this demonstration.

For instance, if we had a model that was there for cladding oxidation, and we looked at the oxidation in the cladding, yes, particulates are happening, and Model 5 we predicted what's happen with ZIRC 4, predicting what's happening for ZIRLO, we might be probably inclined to say, you know, what differences have they seen in the reactors and things, does it justify doing extra work. Is it close enough.

We'd have to use supplemental data to determine how applicable the material is, and that's something that the applicant for an application, if he's got a demonstration data on ZIRLO, and he wants to come in with the improved ZIRLO, I mean, the onus of making the argument that the data on the ZIRLO is for improved ZIRLO falls on him. He would have to convince the reviewer that that's applicable data.

That's one reason, Sam, that we are tinkering around with the idea just in the initiation stages, is there a way to license some sort of a cap that we can put on gas at an individual site, so they can just monitor their own fuel in their own demonstration. But, that's down the line, that's another subject.

You know, if the applicants decide that their cladding is too far off, and that it won't be modeled, then they wouldn't be able to use this.

CHAIR ARMIJO: I can see somebody coming in --

MR. EINZIGER: For instance, I don't believe that the new GE cladding, that has the iron in it, would automatically fall within this realm. That might need some different testing.

CHAIR ARMIJO: Well, you know, let's take this issue, the more modern claddings, everybody is trying to develop claddings that pick up far less hydrogen, right?

MR. EINZIGER: Yes.

CHAIR ARMIJO: So, I would say, let's say you ran your demonstration for ZIRC 4, and it picks up quite a bit. Okay. And, you found nothing bad happened, and you have this new alloy that picks up a third or a fourth, a very small amount of hydrogen. I would propose that somebody would simply say, hey, look, this is a much lower hydrogen pick-up, the problem is hydride reorientation. You have far less hydrogen to begin with. We don't need the demonstration program.

And, is that the kind of argument that the staff would listen or, or would it -- I think, you've got a lot of experience and judgment on this, this ISG is going to be given to guys that don't necessarily have that. And, I think there's got to be some windage on that restriction on the same cladding type.

MR. EINZIGER: We'll take that under consideration.

CHAIR ARMIJO: Okay.

MEMBER SHACK: But, Sam, you ought to look at the Journal of Nuclear Materials paper, look at Figure 21, and look at the difference between the two materials types.

CHAIR ARMIJO: You know, I'm not disagreeing that there aren't differences in materials, but I'm just saying, you've got -- you can't -- it's impractical to require a 15-year cask demonstration from every cladding type. There's got to be another way of solving that problem.

MR. EINZIGER: No, we are not requiring that they do a demonstration. If there's a demonstration out there that they want to use, this is the guidance.

If the demonstration isn't applicable to them, then they have to go to a different method.

MR. TRIPATHI: Bob, I'm Bob Tripathi, with Spentral Storage, structural engineer.

I kind of see where Sam has a little bit of concern, in the sense that we are dealing one type of ZIRC 4 or ZIRC 2, and how do you envelope all kind of different cladding material.

And, I sympathize and I see his viewpoint, because right now we are doing -- I have an exemption request from one of the applicants, and he has got an M5 cladding. It's a pretty old cladding, Babcock & Wilcox Mark 11, Mark 11E.

Now, how do you apply the same criteria when it has a different yield strength, different brittle, different ductility, than ZIRC 4, ZIRC 2.

So, I think the crux of the question is, if we go with this ISG and say, okay, this is what we think it is, does it envelope all kind of ZIRC material. The quick answer is no.

MR. EINZIGER: The question becomes is, how broad do you want to expand the applicability of a demonstration.

CHAIR ARMIJO: Well, see, I just conclude that the demonstration will qualify the material for testing. But then, there has to be some other supplementary method that staff can rely on, who has confidence in, that says, hey, with these other supplementary tests connected to this demonstration on this one material, we can justify other material, particularly, if they pick up far less hydrogen.

MR. EINZIGER: Yes, I understand where you are coming from, Sam, and I think what you are asking is doable with sufficient literature search, et cetera.

I think it's something, though, that would have to be more in Rev 1 than in this one, because it's not something that we can just go back and do a few weeks work on and do that.

CHAIR ARMIJO: You know, I would look to the industry guys to come up with proposals on how to deal with those sorts of things.

MR. EINZIGER: Well, yes, I mean, it's -- it's -- the onus is on them --

CHAIR ARMIJO: Yes.

MR. EINZIGER: -- to make the case. The onus is on us to tell the reviewer how to evaluate the case.

CHAIR ARMIJO: Right.

MR. EINZIGER: Now we are in this ISG, we are telling them, if a demo is out there here's how to evaluate that demo.

The way this is written right now, if it came in to -- the demo came in and had the same type of cladding, there's no issue.

MEMBER SHACK: Well, to be fair, this better be for the guy who is setting up the demo, too, because you don't need this for the reviewer yet, he's got 20 years.

MR. EINZIGER: Well, yes, but --

MEMBER SHACK: These guys will be gone.

MR. EINZIGER: -- I mean, we have to look at it, these ISGs, from two points of view. One is the point of view that's intended. The ISG is intended to give guidance to the reviewer.

Now, we have to look at from the practical side. Soon as it's out there, the applicants look at it and say, not only do they say, well, this is guidance for me, they look at it and say, NRC is demanding this, and we are constantly fighting that battle. We are not demanding it, but, you know, the smart guy looks out there and says, this guy holds your fate in his hand, maybe I should listen to what he's saying. That's just the practicality of it.

MEMBER SHACK: Yes, and he tells him sort of how he has to design a demo.

MR. EINZIGER: Originally, ISGs didn't go through your committee, they didn't go through public review, they were done in house, they were issued in house, and they were posted.

Because they are being used so much by industry, we are going through a more formal process now. This ISG will be going out for public comment, to get feedback from the industry.

MR. TRIPATHI: Bob, I think you hit the nail on the head. This will be our first Rev 0, and as we go longer on the learning curve we'll hear the industry, and then maybe in the second rev, Rev 1 or Rev 2, we'll capture and make it more broader. This is, you know, all I can say.

MEMBER RYAN: It seems to me, Sam, that's a good point, because it's not -- this isn't a product you are putting out, this is a work in progress.

CHAIR ARMIJO: Yes, I understand, and I'm trying to get into that, considering a more general kind of --

MR. EINZIGER: I made a note, Sam.

CHAIR ARMIJO: Just saying --

MEMBER RYAN: So, I guess, Sam, your real question is that some of these comments that you are making and, perhaps, those that are chiming in on, are going to end up as --

CHAIR ARMIJO: Yes, the staff will think

about it, and --

MEMBER RYAN: --points that might end up in the guidance.

CHAIR ARMIJO: -- when you get your feedback from public comment, that you may change some of the wording.

Okay. Why don't you go ahead, Bob.

MR. EINZIGER: We want to make sure that the demonstration is derived by a recognized method, where the peak cladding temperatures are bounded by the peak cladding temperatures in the license.

We want a helium -- it should be helium filled, because that's what most people use, the helium filled. We think that there's a definite benefit in getting immediate results by monitoring certain attributes, the water, the hydrogen, oxygen, fission gas.

We know the fission gas, if we measure fission gas, we know whether we are creating breeches. If we measure oxygen or hydrogen in there, we know whether we are getting into a flammable situation. And, if we measure water vapor in there, we know we are in trouble.

We want to know what the axial fuel temperature distribution is, because that's going to tell us how much and where we can expect hydride reorientation. It tells us where we could expect possibly to be coming to the brittle state. And, we want to have -- and one point that we really debated long and hard is, how long does the demo have to be to be indicative of where you are going.

Part of that is going to be governed by the monitoring. If the monitoring shows no waters, or no hydrogens, it shows no fission gas, one might be inclined to say, well, I can open it up in a shorter duration, maybe ten years is enough to look at what's going on. We can open it up, we look for creep or some other things.

If we are starting -- if we start this up and a few months into it we see water vapor and hydrogen generating there, we may want to open this thing up real early to look at it.

How long is long enough? Fifteen years was long enough for 20 years, and, actually, for low-burnup fuel we went to 40 years. When we did the analysis of that data, we, actually, thought we could go to 100 years, because of looking at extrapolation of it.

With the high-burnup fuel, you'll have to look at the data, and see, you know, we are asking them at this point that if they want to use a demonstration they are going to have to come in with the demonstration data before they get the license extension.

The earliest license extension for high-burnup fuel will probably be within about another 15 years. That is why we are saying probably about 10 should be enough to start with.

We also don't anticipate that someone would just do the demonstration then end it. My own personal view now is, there's no reason to end the demo prior to the time that somebody has determined what the ultimate use of the fuel is going to be, whether it's going to be reprocessed, or put in a reprocessor. We've got no place -- no place to take it anyway. So, you might as well leave it in the demo.

But, that's not for us to say. How long is long enough is going to be dependent on the results that come out.

And, this just goes back over some of the things that we said, some of the things that the monitoring would tell us. You know, one of the problems that's right now in this country, is that we are very quick to dismantle hot cell facilities, and so there is no hot cell facility in the United States right now that could take a full cask into it and open it up and take fuel rods out, such like the TAN facility was at Idaho that was decommissioned. So, there's questions about, well, would we have to put this back in the pool, would we not.

I don't know which way they would empty this, but they'd have to --

CHAIR ARMIJO: I had heard that GE Vallecitos hot cells were being shut down. Is that correct? That used to be very useful, even though it was antiquated.

MR. EINZIGER: -- I was out to see the Vallecitos hot cells about three or four years ago, and I was very impressed by the capabilities they had there, but I was also a little bit shocked by the fact that the amount of work that was going on there was next to nothing.

And, I haven't heard anything directly that they are shutting down that cell --

CHAIR ARMIJO: I guess maybe --

MR. EINZIGER: -- but from an economic point of view it would not surprise me.

CHAIR ARMIJO: -- that's unfortunate, because one of the things, at least in the GE, we had lots of fuel rods that had been intentionally run to high-burnup, in order to explore things. And, they were examined, they put in -- you know, after just normal operation, and after all our testing was done, there were still many segments of well-characterized cladding that could easily be then run through a temperature gradient.

You know, there's a lot of hot cell stuff that could really --

MR. EINZIGER: I think DOE is serving available material in different hot cells to see what there is in terms of test material, but those would all be short term.

CHAIR ARMIJO: They could be short term, they could be very informative, though, about --

MR. EINZIGER: Oh, I'm not saying that the short-term tests are not informative. Short-term tests are very informative, but the purpose of this demo is to look at the long term and make sure what where we are going from short term to long term we don't -- we are not making mistakes.

Any time you extrapolate you increase your risk. The shorter the extrapolation, the less risk. And also, you know, you have to look at demonstrations, it's another way of telling the public have confidence that we know what we are doing, that we are ahead of the game.

CHAIR ARMIJO: I hear you, Bob, but I would do it quicker.

MR. EINZIGER: What's that?

CHAIR ARMIJO: I would do it quicker, and I'd use other methods, if I could get access to other testing methods to get to the same point.

MR. EINZIGER: Well, if I had different resources available to me, I might go different ways also.

CHAIR ARMIJO: Yes. Well, it's not my job to invent, it's the industry's job to figure that out.

MR. EINZIGER: Yes.

CHAIR ARMIJO: This looks like it's going to take a long, long time.

MR. EINZIGER: Well, it is. It's going to take -- it's going to take a number of years to get started. It will take a number of years before actual destructive examinations are out.

We can, from non-descriptive examinations, the monitoring, we can tell what's happening, but it's very hard to predict based on non-destructive examinations. It's when you get into the destructive examinations that you can start making predictions, because you see how things have progressed.

And, Sam, the purpose of these tests are not to say we don't know what's happening. The purpose of these tests is to say, we think we know what's happening, we just want to make sure.

CHAIR ARMIJO: But, you know, if the problem we're worried about most is hydride reorientation, long term almost doesn't mean a whole lot.

MR. EINZIGER: Hydride reorientation is just one of the effects. I mean, we have dismissed creep, like --

CHAIR ARMIJO: Hydride reorientation is a short-term problem.

MR. EINZIGER: Hydride reorientation occurs within the first couple of months. Then you are starting to pool, and over a long time when you eventually pool, that's when you come into problems.

CHAIR ARMIJO: But see, I mean, that tells you when the problem could occur, but the reorientation is defined in a short time.

MR. EINZIGER: Is defined in a short time.

CHAIR ARMIJO: But, we still don't know, and you can't get out of this, you know, how much toughness do you need. You know, what's my criteria for -- you know, suppose I go below the ductile brittle transition temperature, is that a problem or isn't it?

MR. EINZIGER: We are trying to do some testing like that right now at Oak Ridge.

MEMBER SHACK: You know, to me that's a more immediate problem than anything I might learn from my 20 year demonstration, is that --

MR. EINZIGER: Oh, I'm not saying the 20-year demonstration is going to answer any of your problems.

MEMBER SHACK: Okay.

MR. EINZIGER: This is geared towards license renewal. See, right now we've ran 20-year licenses for high-burnup fuel. The regulations allow them to apply for up to an additional 40 years, maybe 40 years after that, 40 years after that. And, all we are saying is that between the first 20 years, before giving them another 40 years, up to 60 years, we just want a little confirmation.

MEMBER SHACK: But, we are already licensing them, the high-burnup fuel.

MR. EINZIGER: There is high-burnup fuel in storage now, based on ISG-11, based on the short-term data.

CHAIR ARMIJO: That's a 20-year license, right?

MR. EINZIGER: 20-years license.

CHAIR ARMIJO: But, if the guy came in today, he says, gee, I've exceeded my 20 years, I need another 20 years, it's high-burnup fuel --

MR. EINZIGER: We are not issuing it.

CHAIR ARMIJO: -- you are not going to issue the license, but then, then what?

MR. EINZIGER: Well --

CHAIR ARMIJO: Tell them to put it back in the pool.

MR. EINZIGER: -- somebody had a foresight to say, as long as you apply for the renewal before the license period runs out, you sort of go into status until a decision is made.

CHAIR ARMIJO: But, one option would be, and I don't think you'd, actually, wind up doing it, is just put it back in the pool.

MR. EINZIGER: I think things are going to have to have some definitive indication that there's an issue before that occurs.

CHAIR ARMIJO: That's what I think.

MR. EINZIGER: But, we do have the license applications in house right now, for people who want to have a longer-term license. And, SFST staff is developing a path forward for how to handle high-burnup fuel, and what we are requiring, and this is sort of a -- we are telling them, okay, if you want to have a license for extended storage, you are going to have to come in with some data before this one expires before you are going to get that granted.

MEMBER SCHULTZ: Bob, you mentioned the Oak Ridge activities that are ongoing, or a plan to look at high-burnup fuel that is just out of reactor.

I'm a little concerned that as you describe it so far today that the hydride, just as an example, is somewhat understood, in terms of its potential long-term performance issues, but not well understood.

So, if ten years from now we look at high-burnup fuel that's been in storage, and find hydride orientation or concentrations, the only thing that we can do if we haven't looked at other features of performance, would be surprise and concern.

And, I'm not sure that we've got a good handle on what don't we want to see. What do we want to see, when we do these examinations on the high-burnup fuel in storage. What would be acceptable? What would make us feel comfortable?

MR. EINZIGER: What would make us feel comfortable, when we open it up eventually, what will make me feel comfortable is if when we are doing the periodic monitoring we don't see water vapor, we don't see, fission products, we don't see oxygen in there.

And then when we open it up, and we look at the fuel, we don't see creep of the fuel, we don't see corrosion.

CHAIR ARMIJO: But, Bob, the water vapor issue is a cask-related drying issue, it has nothing to do with the hydrogen reorientation, unless you expect you are picking up a lot of hydrogen during storage.

MR. EINZIGER: This isn't a demonstration of hydride reorientation. It's a demonstration of the rod peak performance in the typical atmosphere, under typical conditions.

CHAIR ARMIJO: Right, but with the monitoring that you just described, what does that have to do with high-burn up versus low-burnup fuel?

MR. EINZIGER: Nothing.

CHAIR ARMIJO: It's really --

MR. EINZIGER: That has nothing to do with it. Where you would -- except if -- we know with the low-burnup fuel we have no indication there's ever rod failures, there's no rod mechanisms for failure.

If you've got fission products, that would be telling us that we are failing fuel earlier than we expected failure.

CHAIR ARMIJO: Right.

MR. EINZIGER: There's something going on we don't expect.

When we examine the fuel after ten years or so, if we see a lot of corrosion on it, which we don't expect, we see a lot of creep on it, when we opened the rods in the cask up in Idaho, there was, approximately, less than a tenth of a percent creep. That's sort of what we expected.

I wouldn't expect anything different on these, even though there's a higher pressure in them and all, but let's say we found nine tenths of a percent creep. Hey, we are out of the range where we expect to be, what's going on that's different.

A successful test is a null test. We don't see anything. That makes it successful. If we see things happening, then there's issues. That doesn't mean that we can't solve the issues.

If we were to -- if we had rods and had a lot of hydride reorientation, and they sat there and they cooled down so they were down, way down in temperature, then there's still things we could do to transport these things. Put the heaters on the cask, it's a reversible situation. We could bigger impact limiters, and have confidence in our engineering capability of our people.

MR. TANG: This is David Tang. I just wanted to add to this license renewal part of the activities.

We are really talking about the certificate review, meaning that we are going to review, not only the initial certification which could have been issue, say, 18 years ago, or 20 years ago, close to that time frame, and also looking to amendments as of now all of these amendments, some of them may have had, say, a high-burnup fuel, say, approval.

So, for that matter, the high-burnup fuel, such license review will come to visit us sooner than what I think we are just talking about.

In a sense, if you talk about the docket, the 72 1004, which is new home horizontal storage system, I think the license will expire 2015 or '16. So, thinking about that part, the timetable there is much faster than we talk about.

CHAIR ARMIJO: Okay, I think we better move along. I've been holding things up, because you have three more slides, and I want to make sure we give you plenty of time.

MR. EINZIGER: Well, the next one is on the use of the monitoring. It just tells how we can get data. And, even if we never get to open this cask, this is still a successful thing, just by knowing we are actually dry, so we don't have to worry about gnomic action, it will let us know if we are reaching the rods. So, there's success just in the monitoring.

If we do get successful, and we can open them up, we can make predictions, confirmation of creep predictions. And, when I say "we," it's the applicant that's got to do these things. We've just got to review it, but this is the kind of data that will come out of the demonstration.

We can see any effects of residual water, if there's any water left in there. We could look for crud spallation, as it might affect the source term. We can look and see by puncturing rods whether we've had any additional gas release from the pellets to the gap. We can use the data for looking at the models that were used to benchmark the models.

And, there's lots of models based on short-term data, but we'd like to benchmark them for the longer term, since that's what we are using them for.

And, one of the things I think is important is that we are going to hedge against if there's any new degradation mechanisms popping up that we hadn't thought of, and maybe get a control on it before we get too far down the line.

What's our role in this whole thing?

Unlike the first demonstration, where the NRC kicked in close to a million bucks, and was right on top of examining the fuel, and making the plans, and everything else, that's not the goal for this one.

We plan to sit in on the discussions, just as an interested observer. We probably will be doing license review. We would like to be independent observers, and one thing that just is absolutely necessary from the lawyers' point of view is that we have to do independent data review, and draw our own conclusions from it, so that we have the separation of responsibility.

And, the major role in this for us is going to be providing guidance to our reviewers, like we are doing now, and what to look for.

In summary, the ISG-11 Rev 3 provided guidance for storage based on the short-term tests, the predictions of that ISG were confirmed for low-burnup data, low-burnup rods, but there's some changes in the properties, and we want to be in a position to evaluate any demonstration that's been conducted with high-burnup rods, to see that they give us applicable assurance that we can have continued storage.

MEMBER SHACK: What do we monitor now in this?

MR. EINZIGER: Well, the birds make nests, and they take -- very little -- very little. We monitor dose of the site boundary. We monitor some temperatures. I think there's a certain dose at the outside of the canister. There's absolutely no monitoring inside.

And, in public meetings that has been brought up as a complaint.

CHAIR ARMIJO: Now, the temperatures for some of these pooled that have been out there for a while, what temperatures are they reaching as they cool down? I don't think there is such a thing as typical, but if there was, do they get down to a couple hundred centigrade, or lower than that, room temperature, how low do they go?

MR. EINZIGER: Between 100 and 200 degrees C. It depends on the loading, it depends on the initial temperatures.

CHAIR ARMIJO: And, are they going to stay that way for a long time?

MR. EINZIGER: Then it will take a long time to reach that. We have a task that's going on now in the Division of -- or, Office of Research, to do modeling of prototypic temperatures.

Right now, most of the models, since they've only been worried about the high temperatures, always seem to be very conservative in the high direction.

CHAIR ARMIJO: If you were going to try and set up a test that says, hey, look, the lowest you are going to go under practical terms is 100 degrees centigrade, and you want to set up some sort of mechanical property test, it would then be valuable to know what that temperature would be, so that you don't have to go down to zero centigrade.

MR. EINZIGER: Well, obviously, the easiest tests to run are room temperature. And, in fact, the tests that are being run in Oak Ridge are room temperature.

CHAIR ARMIJO: So, you've gone below the 100C.

MR. EINZIGER: Yes. I mean, we can control the temperature in the ring compression test. That was fairly easy, but the bigger the samples you get, and the more complex the testing that you want to do, like the vibration tests that we are doing in Oak Ridge, that set up is not made for operating high temperature. That's just been looking at ambient.

But, modeling is going -- taking place, to determine what the temperature profile is, both as a function of axial radial location in the cask, and also as a function of time.

And, we always seem to get surprises. I mean, I was surprised today when Mike Malone sent me a temperature profile from one of the task members, showing that the peak cladding temperature is up in the plano region. It made no sense to me.

But, it mostly -- by the time it gets off the fuel top, the temperature starts coming down. So you say, why is that important? Well, it's important because determining what the stress is in the rod. So, we do get surprises, and we are trying to do enough to stay on top of the surprises.

CHAIR ARMIJO: Okay. So, this is your summary slide now. Who is going to do this demonstration?

MR. EINZIGER: Not us.

I can tell you what I know. DOE has let a contract to EPRI in conjunction with the Dominion and TN, to do a demonstration with, what is it, $15 million they've allotted?

And, they are in the process of developing at this point. NRC, as far as I know, has no intention of doing the test work, responsibilities and potential goals that we have are the ones that were in that previous slide. We are not the doers, we are the overseers.

MEMBER SCHULTZ: But, one would expect that that incorporates some hot cell examination, not just canister testing, just the monitoring.

MR. EINZIGER: It's our anticipation that before they put the assemblies in the cask for storage, they will remove some rods to put aside for characterization, either at that time or at a later date, and that, eventually, they will have a facility to take rods out of the cask afterwards, and compare the two rods.

CHAIR ARMIJO: These would all have gone through that same transient cask that was loaded, right? I mean --

MR. EINZIGER: Not the ones that were pulled out first. They would be the conditioner rods, prior to when they got loaded into the cask.

MEMBER SCHULTZ: High-burnup rods.

MEMBER SHACK: Yes, but Sam wants to send it through a 400C cycle.

CHAIR ARMIJO: Yes, and find out how much as soon as possible, you know, in a hot cell, and maybe not the ideal long-term stuff, you know, give me near term.

MEMBER SCHULTZ: Yes, I'd agree, and then you know whether this is likely to be a concern.

CHAIR ARMIJO: At least that issue, that part of the issue.

Well, look, this is a work in progress, and it's going out for public comment, and, you know, at some point maybe the industry guys will talk to us about what they are planning to do.

MR. EINZIGER: Well, I do know that they intend to prepare a test plan over the next number of months, and as far as I heard they do intend to put that test plan out for public comment.

CHAIR ARMIJO: Okay.

MR. EINZIGER: We have no control over that.

CHAIR ARMIJO: Do we have any other comments from Members? We have people on the bridge line, I'd like to open it up. There are industry people on the bridge line, so let's open it up and see if they want to make some comments.

MEMBER SCHULTZ: I'd be happy to hear from EPRI or Dominion if they are there.

CHAIR ARMIJO: Yes. I think there was somebody from EPRI.

MEMBER SHACK: The lines open to say something.

MEMBER SKILLMAN: Bob, why we are waiting, can you give us a sense of urgency here? How much fuel is pushing up into the 45 gigawatt days per metric ton? How much --

MR. EINZIGER: Just about everything that's being taken out of the reactor today is probably above that.

MEMBER SKILLMAN: Okay. So, it's everything.

MEMBER SCHULTZ: And, for the last five years for most of them.

MR. EINZIGER: There's a number of reports out showing what the average burnup is in weighted population, but, basically, what's coming out now is going higher and higher, and the limit on the burnup for BWR fuel is 62.5. I think some of the Bs have it up to 70 of the particular cases.

CHAIR ARMIJO: Those are peak pellet kind of things.

MR. EINZIGER: Peak rod average.

CHAIR ARMIJO: Peak rod average is 70 on these?

MR. EINZIGER: I think there's only one design of these things.

Harold, do you have anymore information on that?

MR. SCOTT: This is Harold Scott. I got the number for everybody was like, rod average less than 62, but if you want to play around with what does peak pellet mean, can you justify. And again, there's no -- that's not a rule anyplace, it's just sort of --

CHAIR ARMIJO: But, if the regulation says 62 rod average --

MR. SCOTT: In the terms of --

CHAIR ARMIJO: -- that's what they are going to do, I can tell you.

MR. EINZIGER: I know that at least --

CHAIR ARMIJO: The target is usually a little less than that.

MR. EINZIGER: Yes.

CHAIR ARMIJO: But, you don't want to violate it.

MR. EINZIGER: Sam, I'll make a note to have Paul Clifford send you the latest burnup limits.

CHAIR ARMIJO: Yes. I know some people design on pellets, some people design on peak nodes, and average plane, so there's all sorts of peak burnup criteria.

Okay. Anybody on the bridge line that would like to make a comment?

MR. KESSLER: Yes. This is John Kessler

from Electric Power Research Institute. Can you hear me?

CHAIR ARMIJO: Yes, we can, John.

MR. KESSLER: Okay, good.

Yes, we are leading a team that is going to do such a demo, and I think that what we are planning to do pretty much addresses everything that I've heard on the phone call.

The background is that we just entered a contract with Department of Energy to fund this. It's going to be a five-year effort to get the demo going.

How it's going is that we have a host utility that we are having this done at, which is North Anna. North Anna has three different kinds of high-burnup fuel, but we will get a sense of how the different types of high-burnup fuel will behave.

We are going to put them in a prototypic cask, which is a TN-32, that is a bolted-lid type of cask. We'll instrument it, essentially, exactly like what Bob Einziger just described to you. We will be able to take gas samples for the different kinds of gases that Bob was talking about.

We plan to instrument it to get temperature readings, so that we get differences in the axial temperature and radial temperature, so that we can benchmark the model.

And, part of it is, while I understand that the hydride reorientation issue is a short-term issue, what we really don't know are the exact temperature distributions in the cask that would govern how much hydride reorientation we would expect to get. So, the demo will provide that information and get the information up front.

Part of the other prep for the test is, the rods that will be selected, or the assembly that will be selected, will be the polling rods from them or from sister assemblies that have had the same reactor operating history.

And, we will shift those to a DOE-designated lab or labs to do things like get, essentially, the time equal zero condition of the cladding, so that we can determine whether the cladding experienced creep, how much hydride reorientation is going to occur when we finally finish the test and reopen the cask and take some more rods.

We'll measure gas pressure inside the rods, so we can see what kind of changes will occur during the process.

So, once we load this, which we expect will take a couple years, because we will need to get a license by NRC, we will start collecting temperature and gas sample data right away, so we'll get that information.

Now, there was another point that was made about, well, gee, we are only using, you know, a couple different kinds of rods here, how can we extrapolate it to the whole fleet of rods out there?

What we envision is that this demo is highly important, but it needs to be supported by some, what we call, smaller-scale testing, or separate effects testing.

You had mentioned, for example, you know, some of the rods that are left over, well, let's start by maybe picking some of the rods that have the same kind of fuel that we are putting to the test, do some shorter-term testing, and see if the results are giving you the same thing that when we do this longer-term testing we get the same results.

Then if you do other short-term tests, small-scale tests, things like that, for other kinds of fuel, you might have more confidence that those shorter-term tests are giving you decent indications of how they will behave over the longer term.

So, that's kind of the suite of testing and the general approach that we are planning to take.j

CHAIR ARMIJO: When will you have a

description of this overall program?

MR. KESSLER: Yes, again as Bob said, we are -- we have a deliverable to Department of Energy to develop a test plan, a proposed test plan. My understanding is the Department of Energy will put that out for public comment in the August time frame.

And, we are certainly hoping that among the other public that we get comments from, we will get some feedback from NRC on what we are proposing for the test plan.

And then, we will develop a final test plan, based on the feedback, and then start executing the test plan.

So, we are expecting to get going in earnest on getting the demo up and running, well, excuse me, starting the licensing the design of the special lid, by, say, September or so.

CHAIR ARMIJO: In your, I guess you call it, you said small scale, but let's use the word supplemental, because it's supplemental to the big cask demo.

MR. KESSLER: Yes, that's a good word.

CHAIR ARMIJO: Yes. Are you going to do things like take this irradiated sister rods or cladding and put them through a thermal transient that will be experienced when you, actually, load the cask and dry everything out, and measure the extent of hydride reorientation on those samples, and maybe even mechanical properties?

MR. KESSLER: What we are doing formally through this contract is just the demo. However, the first deliverable that we gave to DOE last week was a recommended -- essentially, a recommended set of supplemental tests, like you are talking about. And, we recommended that they do exactly the kinds of tests you are talking about, to supplement the demo.

So, what we are hoping is that DOE, in addition to funding the full-scale demo along with us, that we are managing, that they do go ahead and fund quite a few of the most relevant supplemental tests.

CHAIR ARMIJO: Yes. The one other thing that I wanted to ask is, do you have in parallel, or already in existence, some analytical models of, you know, of the kinetics, of the redistribution process, so that once you are finished you'd have some analytical tool that people could use that is broader application, is that part of your program at this point?

MR. KESSLER: Yes, in the sense that we are not starting with a blank slate. You know, Bob has provided just some, you know, quick descriptions of the kind of data that already exists, and models have been developed for those data. Some data, just there's not enough of it to develop a good, hard prediction, and collecting more data would be very useful, on, you know, what specific fuel has what kind of hydride reorientation.

Bob mentioned the ductile to brittle transition temperature. That is kind of dependent on burnup and cladding type. We have some information there. We kind of have an idea what is causing those changes in temperature, but some more data from these supplementary tests would be very useful, in addition to what we will, ultimately, collect in the full-scale, long-term demo.

CHAIR ARMIJO: Well, you know, I'm reminded of work that I read, and it was EPRI work, EPRI-sponsored work I think with Anatech, on this hydride dissolution, re-precipitation, reorientation.

MR. KESSLER: That's correct.

CHAIR ARMIJO: And, that says Rashid, Montgomery, I think Albert Machiels was involved.

MR. KESSLER: Those are the folks.

CHAIR ARMIJO: Yes. Well, okay, as long as that's part of your program I'm feeling a lot better, because, you know, it had a mechanistic basis, and it may have been lacking some data. And, you guys can, you know, point out what it needs to make that a very useful tool.

MEMBER SCHULTZ: John, this --

MR. KESSLER: Yes, certainly it did get some data, you know, to fundamentally feed the models, but, certainly, one of the most important aspects of the demo is the confirmatory data that says, all of these supplementary tests are really pointing in the right direction of how fuel really does behave in the long-term storage.

MEMBER SCHULTZ: -- John, this is Steve Schultz.

I had a question related to the characterization of the assemblies that might be selected.

MR. KESSLER: Yes.

MEMBER SCHULTZ: Are you looking for what you might consider to be modern fuel, in other words, fuel that's reached high-burnup within the last, let's say, eight to ten years? In other words --

MR. KESSLER: Yes. We are planning to -- the three types of fuel are ZIRC -- high-burnup fuel are ZIRC 4, ZIRLO and M5.

MEMBER SCHULTZ: Right.

MR. KESSLER: So, that covers different composition and different finishing types, re-crystallized, fully annealed, partially annealed, cold work stress relief, those kinds of aspects, in addition to differences in the composition.

So, yes, we are covering those three major types of PWR cladding.

CHAIR ARMIJO: But, you are not -- you are not covering the BWR ZIRC 2 variants?

MR. KESSLER: No. We are using just the fuel that's available at North Anna, which is the PWR.

So, this could be, you know, a perfect opportunity for some supplemental testing with BWR fuel.

CHAIR ARMIJO: Yes. Yes, I think you'd have to do -- you'd have to do something like that.

MR. KESSLER: Right. And, some of those data already exist.

CHAIR ARMIJO: Okay.

MEMBER SCHULTZ: In the characterization study, might you look at more highly-corroded, you know, cladding?

MR. KESSLER: Well, we'll look at what we -- in the sense, we'll see what we see. When we take these high-burnup rods, they will have whatever oxide thickness goes along with those. When we go to do some of the structive exams, I'm assuming that DOE will have the labs take a look at, well, how uniform are these oxide thicknesses, do we have any local differences in hydriding or oxides or things like that.

I would expect to see some, in the sense that if you have spallation you can get higher concentration of hydrides under the spalled area. That's well known.

So, we'll be looking at the properties that go along with the high-burnup fuel. I don't think we'll be looking, specifically, for highly-corroded fuel, but something that is prototypic.

MEMBER SCHULTZ: Sounds good, thank you.

CHAIR ARMIJO: Okay. Any other questions for John?

Okay. Well, I think I'd like to thank Bob and John also for your input. I think it was very informative. We've heard a lot of things. I've got to think about this. We are going to have -- probably going to have a briefing to the Full Committee, but we may not, because it might be better to hear what happens after you get your feedback from the public comments, and you have something closer to final.

MR. EINZIGER: That should be in the Federal Register within the next month, typically, 45 days period for response, so some time this summer.

CHAIR ARMIJO: Well, I'll be polling the Members of the Subcommittee to see what they think, because it really wouldn't be -- it may not be useful to have a, let's say, your Rev 0 review and discussion, when you are just going to be, you know, addressing the public comments, and input from the DOE program, and things like that.

But, we will want to keep track of what's going on.

MR. EINZIGER: Sure.

CHAIR ARMIJO: I'm personally interested in the shorter-term experiments and analyses, simply because that's in my time frame. Twenty years, I'm not so sure.

But anyway, I'd like to thank you, Bob, and the staff, for really good presentations, and a lot of good discussion.

With that, I'm going to adjourn the meeting.

(Whereupon, the above-entitled matter was concluded at 2:35 p.m.)

ISG-24
The Use of a Demonstration Program as Confirmation of Integrity for Continued Storage of High Burnup Fuel Beyond 20 Years

Robert E Einziger, Ph.D.
NMSS/SFST/SMMB

May 22, 2013
presentation at
ACRS Meeting

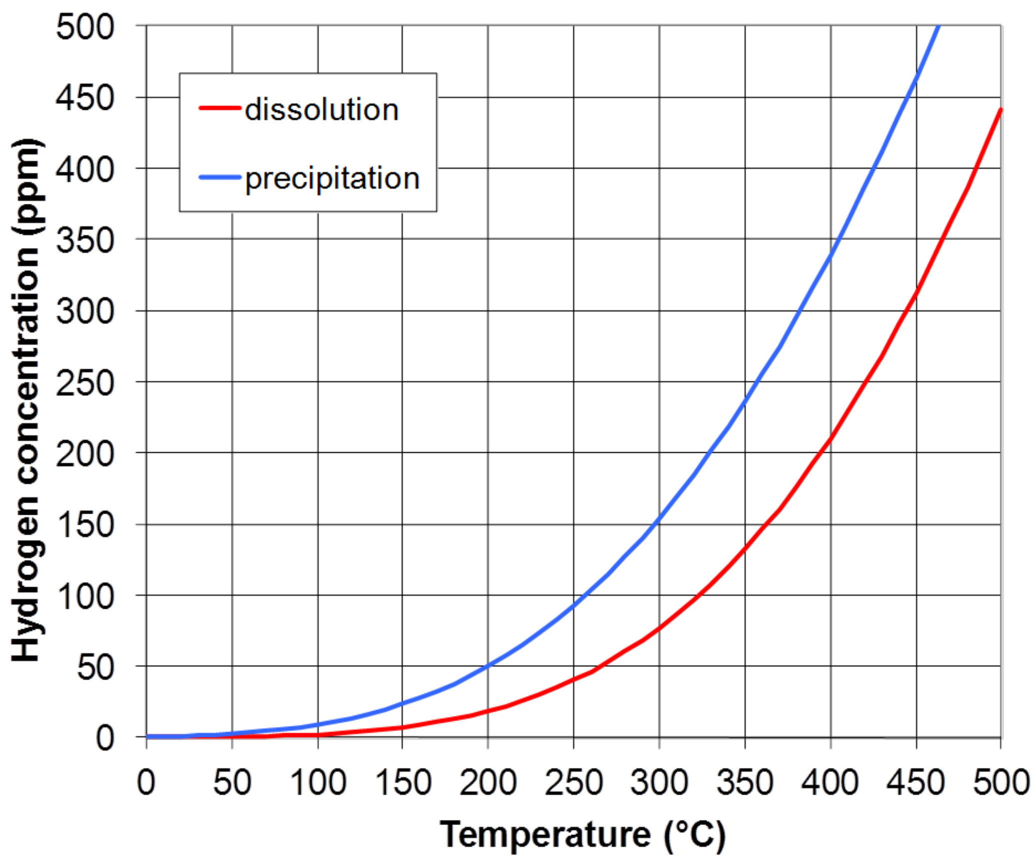
Current Guidance- ISG-11 Rev 3

- Sets temperature limits for storage to prevent cladding degradation
  - 400 C for normal operation
  - All Zirconium based cladding types
- Basis
  - Prevent cladding creep to exceed 1%
  - Thought to prevent hydride reorientation
  - No cladding corrosion issues (acceptable drying + He)
- Confirmation for low-burnup fuel by demonstration test in Idaho

Regulatory Basis:

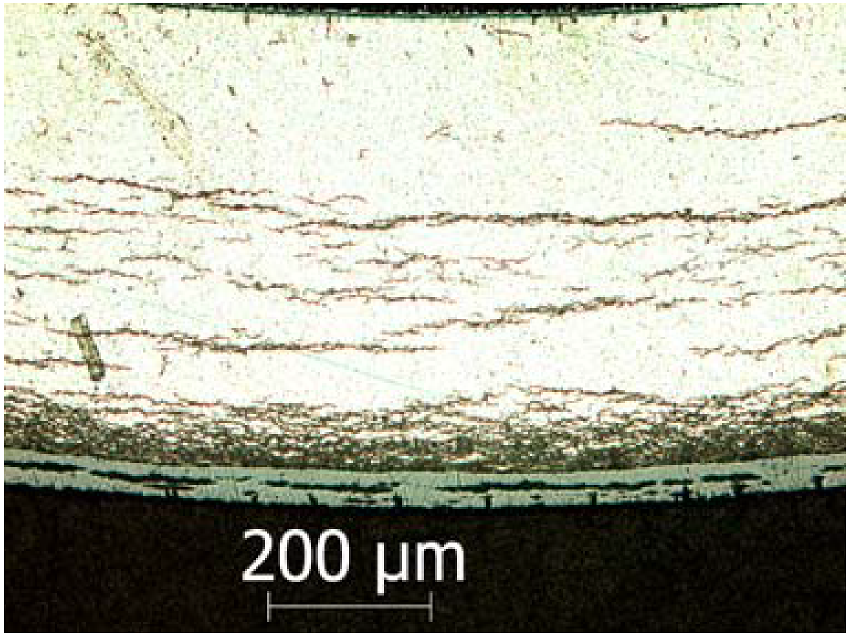
- 10 CFR 72.122(h)(1) The spent fuel cladding must be protected during storage against degradation that leads to gross ruptures or the fuel must be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage.
- 10 CFR 72.122(l) Retrievability. Storage systems must be designed to allow ready retrieval of spent fuel, … for further processing or disposal.

Hydride precipitation

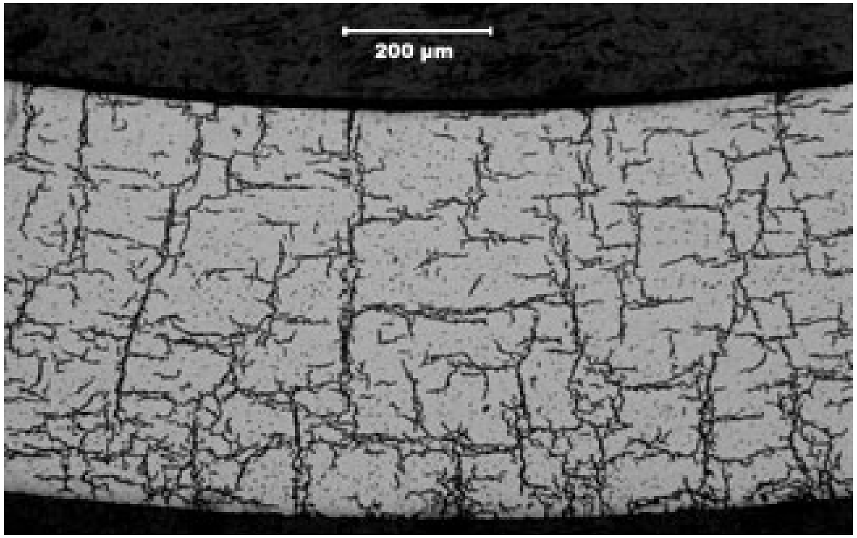


Hydride Reorientation Examples

High-Burnup ZIRLO,520-wppm Hydrogen
140-wppm-H below Hydride Rim



135-MPa hoop stress at 400°C and cooled at 5°C/h, 190-wppm hydrogen (brittle at 150°C)



ISG provides guidance to the reviewing staff

- if a demonstration of high burnup fuel (HBF) has the necessary properties to qualify as a method that an applicant might use in license and certificate of compliance (CoC) applications to demonstrate compliance with 10 CFR 72.122(h)(1) and 10 CFR 72.122(l).
- This guidance is not a regulatory requirement. Alternative approaches may be used to demonstrate safety and compliance, as appropriately justified by an applicant.

Differences between low and high burnup fuel (>45 GWd/MTU)

- Rim region in the fuel pellet
- Greater fission gas release
- Thicker oxide layer
- Higher cladding stress
- More cladding hydrogen content

NRC View of Purpose of DOE HBU Fuel Demonstration

1. Serve the same role that the previous demonstration at Idaho in the late 1990s serves for low burn-up fuel
2. Confirm with longer term data that the predictions of fuel behavior based on short term separate effects tests, many on lower burnup fuel, are still valid, after a substantial storage period (~ 10 years). The behavior of the cladding for the renewal term will depend on its physical condition at the end of the initial 20 year storage period.
3. Provide data to benchmark and confirm predictive models, and updating aging management plans.
4. Provide confidence in the ability to predict performance, and identify any aging effects that could be missed through short-term studies
5. Determine, if after storage, when the fuel cladding temperature has dropped below the DBTT under normal conditions of transport that there is reasonable assurance that the fuel maintains its configuration
6. Anticipation by NRC that the demonstration will not be terminated until the ultimate duration of dry storage has been determined.

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Demonstration Criteria

- The burnup of fuel in demonstration program to bound burnup of fuel.
- Same cladding type as fuel in license application.
- Canister dried by a recognized method with peak cladding temperatures (PCT) that bound PCT in license application.
- Interior of a He-filled canister continuously or periodically monitored for H_2O, H_2, O_2 , fission gas and fuel cladding axial temperature distribution.
- Temperature profile of fuel typical of that expected in full canister.
- Data from demonstration program must be indicative of a storage duration long enough to justify extrapolation to the total storage time requested.
- Evaluation of the data from the monitoring available prior to the end of the currently approved storage period.

Uses of Monitoring

(sufficient but not optimal if there is no fuel evaluation)

- Gives storage performance data from the start of demo
- Monitoring before and after tells if fuel is disrupted during transportation. Monitoring during transport desired but not necessary.
- Monitoring required
  - Temperature –evaluate degradation models, code benchmark
  - Kr – fuel rod failure
  - O_2, N_2 – cask leakage, radiolysis, corrosion
  - H_20 – drying
  - H_2 - flammability
- Optional monitoring
  - Testing of remote monitoring systems if it doesn't delay demo
  - accelerometers

Additional Information from examination of the fuel at periodic intervals

- provides confirmation of creep predictions
- Effects of residual water if any
- CRUD spallation for source term analysis
- Variability of performance between rod and cladding types
- Identification of failed rods if any
- Fission gas release from pellet to gap if any (increase in cladding stress)
- Change in hydride structure of cladding
- The models of the phenomena used for the first 20-year predictions can be used for the TLAA beyond 20 years.
- New degradation mechanisms are not operating

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Potential Role of NRC in Demonstration Project

- Planning Discussions
- Licensing Review
- Independent Observation
- Independent Data review and conclusions
- Guidance to reviewers based on results

Summary

- ISG-11 Rev 3 provides guidance for storage based on short term tests
- Predictions of ISG-11 confirmed for low burnup cladding by demonstration tests at Idaho
- Change in properties of high burnup cladding requires reconfirmation of ISG-11 results
- Demonstration program is one method for applicant to show ISG-11 guidance is good for high burnup fuel
- ISG-24 provides guidance to reviewers to evaluate demonstration program if used by applicant to justify license renewal terms