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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE

143rd MEETING

(ACNW)

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WEDNESDAY,

JUNE 25, 2003

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ROCKVILLE, MARYLAND

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The Advisory Committee on Nuclear Waste met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 8:30 a.m., Dr. George Hornberger, Chairman, presiding.

COMMITTEE MEMBERS PRESENT:

DR. GEORGE W. HORNBERGER, Chairman

DR. B. JOHN GARRICK, Vice Chairman

DR. MILTON N. LEVENSON, Member

DR. MICHAEL T. RYAN, Member

ACNW STAFF PRESENT:

SHER BADAHUR	Associate Director, ACRS/ACNW
HOWARD J. LARSON	Special Assistant, ACRS.ACNW
NEIL COLEMAN	ACNW Staff
MICHAEL LEE	ACRS Staff
RICHARD K. MAJOR	ACNW Staff

A-G-E-N-D-A

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

(8:30 a.m.)

CHAIRMAN HORNBERGER: The meeting will come to order. This is the second day of the 143rd meeting of the Advisory Committee on Nuclear Waste. My name is George Hornberger, Chairman of the ACNW. The other members of the committee present are John Garrick, Vice Chairman; Milton Levenson, and Michael Ryan.

Today the committee will (1) discuss the spent fuel characterization Project with members of the NRC staff; (2) hear an update on Waste Management Related Research from the NRC Staff; (3) discuss plans for next months ACNW Performance Confirmation Working Group; (4) discuss the committee's approach for the 2003-2004 ACNW Research Report; (5) elect ACNW officers for the period from July 1, 2003 through June 30, 2004; (6) prepare ACNW reports on recent committee reviews.

MR. LARSON: If any.

CHAIRMAN HORNBERGER: If any, right. Richard Major is the Designated Federal Official for today's initial session. This meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act.

We have received no written comments or requests for time to make oral statements from members of the public regarding today's sessions. Should anyone wish to address the committee, please make your wishes known to one of the committee staff. It is requested that the speakers use one of the microphones, identify themselves, and speak with sufficient clarity and volume so that they can be readily heard.

So, today's first session is on Spent Fuel Characterization Project, and Milton Levenson is the cognizant member of the committee, so I'll turn the meeting over to Milt.

MR. LEVENSON: Thank you, George. I'll just make one small comment before we start. Yesterday we spent almost the whole day on what I would call virtual reality in the world of the computer. Occasionally, it's nice to get back and find out what the real physical world is like, get real evidence to support what's going on elsewhere. So, I'll ask Harold Scott to go ahead and make his presentation. No pressure.

MR. SCOTT: Thank you very much. I was going to say that yesterday you talked about the repository, and today we're going to talk about the

real fuel and the cask, so that was a good introduction to what we're going to cover today.

(Slide)

I'm with the Division of Systems Analysis and Regulatory Effectiveness. Jack Rosenthal is my boss. Let me also mention some of the other principals that have been involved in this project. It goes way back, but just the recent part of it is the part where I've been involved in. Dr. Suh, in the back, has been one of the lead persons in research on this project. Roger Kinealy (phonetic), works in DVT, your old division, recently retired, he's been involved in this for some time. The User Office, Spent Fuel Project Office, Chuck Enterante (phonetic) has been a leader on that side. They are not here today because they are meeting with DOE on a follow-on program with maybe another cask with other fuel rods, higher burnup fuel rods. A couple of people at Argonne have been principals in this, Dr. Han Chung Tsi, and Bob Einziger. Bob is here today if you have any questions for him. He's the one guy that's sort of been on this program from, what, '85 or earlier?

MR. EINZIGER: Yes.

MR. SCOTT: And also this program is jointly sponsored with EPRI and John Kessler is the

manager of their end of it.

(Slide)

So, why are we interested in the characteristics of irradiated fuel? We need to know if the cladding will maintain its integrity in the dry-cask and in the repository. It may not make too much difference if there is a little perforation hole in the cladding because there's not much gas, radioactive gas that can get out, and if the fuel doesn't relocate, you don't have to worry about criticality or shielding or decay heat. But there does seem to be a sense that these rods will be intact for a long time. So some of the information that we're trying to gather is to show how does the rod behave during burnup, how does it behave in the cask?

So, we've done things like profilometry rod, gas analysis, creep testing. The post-creep mechanical properties are still to be done. We have three sets of rods, medium burnup and high two high sets, BWR and PWR. Even though this says focus is the Surry rods, I'll be covering all three types of rods today.

(Slide)

Regulatory issues. One of the things that I'll point out here is that in Part 72, there is the

idea that these fuel assemblies might be shuffled from time to time, maybe they'll be changing casks or when they get to the repository they'll be put into different cans, and so one of the ideas from Section 122 of Part 72 was that "fuel during storage will not pose operational safety problems with respect to its removal from storage". So you will have to be able to handle these assemblies, so therefore they need to have some sort of resistance to failure.

(Slide)

We're talking now about the Surry rods which had a medium burnup. We made a lot of effort to try to figure out if they changed the diameter during the cask storage. Well, we didn't know exactly the diameter when they came out of the reactor, but from various efforts to take averages and measurements, it looks like there was very little expansion of the cladding during the storage.

These numbers for gas release are well within the range for this style of fuel from that vintage.

This is relatively low oxide thickness and the right amount of hydrogen for that amount of oxidation thickness.

We did make these measurements. What this

means is that the hardness means the cladding is harder because of the irradiation and therefore it's stronger. So we've done the creep tests, I'll show you those results, and we're still going to do mechanical properties tests.

(Slide)

Let me not get into the characterization of all three types of these rods.

(Slide)

We're not only worried about dry-cask storage, but we have a LOCA program that's going to use the results, so there were several reasons for characterizing these rods. But in the case of Surry -- and I don't know if you've had a presentation on this sometime in the past, but there was a cask that was put at Idaho 15 years ago and it was opened recently, and these rods were in it. and they took out one bundle -- I'll show you that in a minute -- and examined a few of the rods. We also have rods from Robinson that were driven over many cycles to rather high burnup for the time. The boiling water reactor rods from Limerick are relatively recent rods.

(Slide)

And this is the kind of things that were done for all of these. One of the reasons we do the

actual gamma scanning at the hot fill is to make sure that the pieces of the rods -- we get the rods in sections. And so if somebody says, "Well, this part is the third part and this is the fourth part", we want to be sure we keep them straight.

Hydrogen is going to turn out to be an important factor, I don't think we recognized that in the past. We're also doing isotopic analysis of the Limerick and Robinson rods. This will be used by the people that run the code, so there is a little bit of code work, to see if the amounts of --

MR. GARRICK: Where is this work actually performed?

MR. SCOTT: At Argonne, Argonne East.

MR. GARRICK: Argonne East.

MR. SCOTT: The cask was in Idaho, so the rods were taken out of the cask -- and let me put up the next slide here --

(Slide)

-- were taken out of the cask in Idaho and sent to Argonne West where they punctured them, did the gas measurements, and cut them into smaller lengths and they were then shipped to Argonne East where we have hot cells, and did most of the characterization work. So most of the work I'm

talking about was done at Argonne East.

MR. GARRICK: Okay. Thank you.

MR. SCOTT: So this is the bundle in the cask that we took out.

(Slide)

One of the ideas of this cask program was to say what are the temperatures that rise in the cask, so they had some thermocouples inside the cask originally, and they changed it from gases. And so the important point is that these rods in the cask saw as much as 400 degrees C, and that turns out to be a number which the Spent Fuel Project people use now for a limit. They don't want the rods in the cask, the cladding, to be higher than that number 400 C.

(Slide)

So here is our first micrograph of one of these. And if you've seen micrographs over the years, this looks pretty much normal. It has cracks. These little spots here may be a little chunk that came out when they were preparing the sample for observation. And as I said before, by measuring this outside diameter, there doesn't seem to be any creep that occurred during the cask storage.

MR. GARRICK: Was the 400 degree temperature a center-line temperature, or surface

temperature?

MR. SCOTT: That would be the surface temperature. Since the decay heat is very low, the rest of the rod is not more than a few degrees higher than that, but that is the surface temperature.

(Slide)

Here's another picture now of a blow-up of the cladding -- and I'll have some more cladding pictures later. This is the oxide layer out here. I think this cladding did not have much crud on it. And this hydride -- I'll talk about that a little bit later -- but we don't see any orientation that goes in the radial direction, which would make it weaker.

(Slide)

Now I'm going to jump to the Robinson. These rods, as I showed before, have much higher burnup, much higher fluids. They also have more hydrogen. These little lines here -- as I mentioned, they come in segments. This is a piece, this is another piece, another piece, and this downscale line here is just the edge of the piece. So the destructive examinations were taken at this location and this location. This looks normal.

(Slide)

So now we can see in this picture more of

these little hydrides in here, which we expect for high burnup rods. Before we had a couple hundred ppm, now we're up to about 6- or 700 but, once again, they have this in the circumferential direction.

(Slide)

Now I'm on to the boiling water reactor rods. Same story here. Chunks that come in -- since these are 12-foot long, the hot cell couldn't take such a long piece, so we have different sections. It just means that the burnup sample was taken here. Also, about a 10-inch section was taken for our LOCA tests, which aren't related to storage.

(Slide)

Once again, here is a picture of this boiling reactor fuel, same cracking. There seems to be more gas out here in this edge, and -- I don't know if you can really see it -- but it looks like there's more a difference down here than there is up here. This rod is along the edge, so we think there is a power tilt across the rod which may give different behavior to the different side, edge side.

(Slide)

Now one of the things that might cause some concern is if the inside of the cladding has some damage or change as a result of the burnup. So we were

looking for -- as to whether there's any bonding between the pellet and the cladding, or whether some fission products come out here and maybe cause any corrosion layer along the edge. This kind of rod has a liner, if you're familiar with that. There's a zirconium layer on the inside of the cladding. So let me show you now another picture here that's a little bit more closeup of this.

(Slide)

Recognizing that we take one or two samples out of that whole rod and sort of assume that the rest of the rod is similar to what we're looking at.

MR. LEVENSON: The samples you took were from the highest burnup areas, right?

MR. SCOTT: If they're in the middle. I think we said 27 inches above the center line, so that would be in the highest -- yes. These are the highest burnup in -- so, yes, we're getting -- and that's consistent then with that number -- 57 I think I said was the burnup.

MR. LEVENSON: Normally, the numbers that are reported for burnup are average for the whole subassembly.

MR. SCOTT: Yes, assembly average.

MR. LEVENSON: But you actually picked quite a bit -- somewhat higher than that --

MR. SCOTT: The number I'm saying, the 57, is that rod peak. So maybe the rod would be at 54 and the assembly might only be at 48.

(Slide)

Coming back to what I mentioned before about the hydrides -- and let me just dwell on this a little bit here. When they make a measurement of the hydrogen content, that's for the whole sample. They take a piece of the sample and measure all the hydrogen that's in it and divide by the weight to get this weight fraction. But then by looking at a high magnification picture, they can sort of see where these hydrides are. When the reactor is at full power and this amount of hydrogen -- it's all dissolved. But when it cools down, it's in the cask or in the pool, or in the laboratory for examination it's at room temperature. And there's still some dissolved at this level, but also some precipitates out. And we noticed that there was more precipitation here in this liner, and you can see that there's less here. So it's migrated from this area over to this area, and the reason for that is this has less oxygen in it. The Zircaloy has maybe .1 percent oxygen as part of

its normal fabrication, but as I said before, this is zirconium has much less oxygen, so it has a tendency to absorb that hydrogen. The hydrides can cause cracking, is why we are concerned about that.

(Slide)

So let me summarize now the Surry and the Robinson and the Limerick. These rods look really good after having been in storage for 15 years. We didn't find any extra gas release or creep, and ho hydride reorientation, even though it was up to 400 C at that initial storage.

(Slide)

The Robinson. We've seen this, that when you have high burnup you get this tight bond, but there doesn't seem to be any particular fuel/cladding interaction. These had relatively high oxide thickness. This is the maximum, the whole rod. And in the PWR, the maximum occurs toward the top. And this is about the right amount of hydrogen for this given oxide.

I'm going to go on to the creep test we did for these. This LOCA is part of another program, and we're making the cladding material property measurements which will be used by the computer codes to calculate behavior.

(Slide)

Finally, the BWR rods. You get less oxide in the BWR. In this case, the fission gas was measured at the Vallesidos Lab in California before the rods were sent to Argonne, and it seems to be higher than would be expected for a bunch of rods. But these rods came from a lead test assembly, and maybe because they were on the edge and where they -- it wasn't higher than expected, but it's higher than the average. And I don't know if I showed you a Vu-graph or not, but there seems to be little microcracks in the fuel that could cause the gao to release more. And I did show you these fission products in the gap. But the rods were in good condition.

(Slide)

Now let me go to the thermal creep results.

(Slide)

The ACRS received a presentation on this in October, but I'm going to give you our current results as of just recently because these little specimens are still in the furnace, some of them, and so we have some current results. And I'll be talking about Surry and Robinson. The big difference, of course, is the amount of fluence and the amount of

hydrogen on these.

(Slide)

First I'll talk about the test. The little specimens are 3 inches long. We put zirconium oxide pellets inside to just take up the volume. We have a pressurization system that can put this much cladding stress, even though we don't go that high, and I'll show you that we can maintain the pressure control, and I'll show you a little bit about the measurements we make.

So what we're going to get out is hoop strain and strain rate which was used by the computer codes, and it will turn out that this number turns out to be sort of the same for these two sets of data, but there's quite a bit of variability in the creep strain for cladding.

(Slide)

So here is this little specimen, the sample. It's attached with a tube that is going to come out of the furnace and be connected to the gas system.

(Slide)

So here's the specimen down in here, and this connection that comes out of the furnace. Some of the furnaces will take the one sample and some will

take three samples. So the furnace can be at a given temperature, and then you can put a pressure on this to get the stress you want in the wall. And we tried to keep the pressure constant at all times.

We also discovered that the farther down in the furnace that we can get the specimen, the more uniform across the length the temperature is because it turns out that at high temperatures it's really sensitive to just 5 degrees C difference. You get a different diameter increase.

(Slide)

So as I say, some of these specimens can have multiple -- some furnaces can have multiple specimens. And we have one set of these in one area, and another set of furnaces in another building. These might be sort of called hot cells, but since the samples don't have any uranium in them, they've been cleaned out, but they are still radioactive, and so they do have to sort of keep them inside.

(Slide)

So these little devices here are the pressure controllers, and in a minute I'll show you some of the curves of the data. So they're 1, 2, 3, 4, 5 for the 5 specimens that will be in the -- and then in behind this wall here is the cell where those

furnaces were at that I showed you in the previous Vu-graph.

(Slide)

So what we do is we raise up the temperature, we then raise up the pressure. It sits here for a certain amount of time, and then we depressurize first, and then we let the temperature down. We have to do this because we need to make the measurement separate, we're not able to do an in situ measurement.

So here is an example of the pressure control. It sort of leaks off. There may be a leak out of that swage lock or something. So then the pressure will come back up, and this is the period -- you can see here hours between these little bumps, and this is a small enough pressure differential, 10 degrees, that the stress change is not hardly any at all.

(Slide)

This is the device that makes the measurements. You take it out of the furnace and you bring it over to this device, put it in here, this will rotate, and then the laser can measure the diameter. So we measure it -- and this thing can move back and forth, so we're going to get a longer specimen -- we're going to get 1, 2, 3, 4, 5

measurements. We rotate it around -- 1, 2, 3, 4, 5 back -- and you'll see some figures here in a minute. We can also measure the length of the specimen to see if it's changing.

(Slide)

You might say, "Wait a minute! What are these little sharp points?" It's just the way that the measurement is made. The cladding is really round, but it may be a little bit higher dimension on this side than this side, but as you notice, as time goes on it gets very round. So if the cladding had any ovality to start with, as it creeps it becomes rounder and rounder.

And what we might watch for, if it's getting ready to fail, we would begin to see sort of a swelling portion out here and it would get a fat place, and we'd say, "Uh-oh, it might break pretty soon". But these aren't very big diameter changes.

(Slide)

So this is the matrix now of the tests we did. We have 1, 2, 3 different temperatures and some different stresses. This stress is substantially than in the reactor. If you say, okay, this rod in the reactor may be at -- in fact, it's probably under compressive stress in the reactor -- but in the cask

at 3- or 400 C, the stresses are maybe only 100, but we wouldn't get much creep if we only tested them at that, so we need to get the higher stress in the cladding to make a useful measurement in a reasonable amount of time.

Then, as I said before, we're trying to get this secondary creep, which is a steady-state creep number which can be used by the computer codes for calculating.

(Slide)

So here is sort of the results of those. None of them had any failure. They all maintained their pressure boundary. These are the ones that had destructive examination, but we haven't done these bend tests yet. So you can see here we had quite a few hours on some of these. Here's one that got -- and I'll show you a graph in a minute -- up to almost 6 percent strain at that failure. I think a lot of people would say "Wait a minute, irradiated cladding can't possibly go above 3 or 4 percent".

MR. GARRICK: In the casks themselves, are the fuel assemblies constrained laterally or actually?

MR. SCOTT: I don't believe so. Let me ask -- do you know, Bob? Some casks are horizontal and some are vertical.

MR. GARRICK: I'm thinking in terms of the kind of --

MR. EINZIGER: Bob Einziger, from Argonne. In this particular test, the assemblies were just put in a basket normally unreconstituted, so they were unconstrained.

MR. GARRICK: Do you know how they would be in the cask?

MR. EINZIGER: They weren't constrained in the cask. This was a vertical cask, and they were just sitting in the basket.

MR. SCOTT: I think that's normal, that they have --

MR. GARRICK: For the kind of movement or changes in creep you have here, I would guess the condition would be unconstrained.

MR. SCOTT: Oh, are you saying if I were to swell up a lot, I would contact a grid and I might put an axial load --

MR. GARRICK: Yes.

MR. SCOTT: This amount of creep is not enough to compress the grid strain and lock the rod in -- no.

(Slide)

In this particular specimen, we had it at

one pressure and got out to here. We had this steady-state creep. And then we changed the pressure to a higher pressure, and now it gets on a different creep strain, and this is where we got up to -- with still no failure. And I think I may have a picture that shows it's still round here without any thinning of the cladding.

(Slide)

Just a minor point here. Since we're measuring the Od of the cladding with that laser device, what we want to sort of keep track of the wall average hoop strain, we make this little adjustment. So different cladding thicknesses would have a different adjustment factor.

(Slide)

Here's what I'm saying, at this highest strain, it's still very round. We don't see any evidence that it's beginning to balloon out or creep out preferentially on one side. And this was 422 -- well, I guess it's more than a few MILs growth -- and particularly we think that the thing has additional creep ductility left, so that if it got hot or had a higher pressure, it might go some more without failing.

(Slide)

I'm going to now show you a series of graphs to sort of -- you can see the differences. I mentioned before it's sensitive to pressure and temperature. So here's one at a constant stress, one sample and another sample that had the same pressurization so they had the same stress on them, and you can see substantial difference here by just 20 degrees C in these rates.

(Slide)

And here's one now, if I hold the temperature constant and change the pressure, I can get sort of a similar difference at one temperature by just changing the pressure a little bit. As I said before, these pressures stresses are substantially higher than the rod actually sees. And I think that's why we didn't see any creep in the Surry rod, because they just don't have that much internal pressure.

(Slide)

Here's one now where it's high temperature, 400 degrees Cc. This is sort of the limit, and the interim step guidance that Spent Fuel Project Office recently put out last summer. And it looks -- like this specimen is still in the furnace, but they seem to be coming along here maybe at the same rate. You expect since this has lower stress,

that it will come down a little bit this way as it goes.

So just to summarize on these Surry specimens, these are the ones -- the ones I just showed you -- these are in the furnace now, and we're getting some measurements from these, and they will continue. The rest of them have been terminated.

If the DOE people for the repository, because the temperatures are lower, may find some tests -- we have more samples, we have furnace space. If they want these, we'll do some more tests at lower temperatures, maybe 320-340 degrees C, but then it might take a whole year to get a tiny amount of creep.

(Slide)

Now let me go to the higher burnup Robinson rods. We had sort of the same set of measurements that we made on them. As I mentioned before, this is the maximum burnup on the rod. This was a different rod that had a little lower burnup, but it had gadolinium in it. I don't think I had any pictures showing the examination of that rod.

As I said, they have high corrosion thickness. We sort of have a -- we call it a limit, but it's not a rigorous limit -- but we try to maintain the cladding with less than 100 microns of

oxide thickness. At one point, the Spent Fuel Project Office said, "Okay, you can load fuel in the casks as long as it doesn't have higher than 100". And the utility said, "Okay, that's fine". But then Spent Fuel Project Office said, "But you have to measure it, you can't just say 'oh, it's a calculated value'". So they said, "We don't like that". So that's where we got back to this 400 degrees C criterion instead of a limit on how much oxide thickness it was because, once again, this oxide thickness sort of tells you how much hydrogen there is, and hydrogen is what maybe makes the cladding -- has a propensity for it to fail.

MR. LEVENSON: When you pressurized the rods and got measurable amounts of creep, did you get any flaking off of that oxide that you could find at the bottom of the furnace?

MR. SCOTT: I don't believe that they saw any. It's hardly enough movement to --

MR. LEVENSON: Well, the 5 percent --

MR. SCOTT: But I'm saying those rods for the Surry didn't really have a lot of oxide. These that have a higher -- these might flake off. We'll have to watch for that. I think they have a good idea of what they look like on the outside, and we would be able to see a little chunk that fell down in the

bottom. But these would be much more likely to have that happen. Make a note of that, to ask those guys up there to watch for that.

(Slide)

So we're going to do the same thing with the Robinson rods, in the same -- but as I said before, they have higher fluence and higher hydrogen content, and we have one of them cooking. We wanted to sort of see what the creep rate was so we can predict how long it will take to make the other measurements. And I'll show you in a minute the test matrix for these. And as I said before, we have two sets of furnaces, two sets of multiple furnaces.

(Slide)

So here's this matrix now, and as the previous Vu-graph said, we're emphasizing the 400 degrees C. WE also think it's wise to make one at a higher temperature. If we have some data, sometime later we could maybe raise this 400 degrees C limit to a higher number. We also don't like to extrapolate too far, so we do need to try to get some specimens at a lower temperature, and by having a bunch of them at the same stress, we can see the dependency.

(Slide)

I think that I may have shown this figure

before and pointed out that these hydrides, the little dark spots, are circumferentially oriented. But what we're looking for now, as I said, is increased hydrogen, increased fluence. So do those make a difference on the creep? The models that we have say that that would.

(Slide)

So here's the Surry specimen at the same conditions, 400 degrees C, and this stress level. At some point here, it looks like now this rate is higher. You might say, "Wait a minute. If these are harder because they have more fluence and more hydrides, why would they creep more?" And I'll see if I can answer that later.

(Slide)

Once again, at some time we pull the specimen out of the furnace, made these diameter measurements, put it back in the furnace, three or four weeks later at another time we take it out, and so it keeps growing, so these different measurements are at different times, but the stresses -- the pressure is always the constant. So it turns out that this stress may change a little bit over the lifetime because we don't try to change the pressure to try to maintain exactly the same stress. And once again,

still no swelling on any one side, implying that it continued to creep without failing.

(Slide)

So here's the same kind of results we saw before at a particular stress level, the higher temperature causes a higher strain rate. And the models have temperature-dependent and fluence-dependent factors in them.

(Slide)

Here's one now at higher stress but lower temperature than the other one. And in this case now you see -- it's what I said before -- we sort of expect this one to have a lower creep than the lower burnup Surry.

(Slide)

This is what people were really interested in, do these rods have some creep ductility left in them after being in the cask for a long time, if they were to be taken out of the cask, put in a different cask, had to be dry, they might heat up again. We also didn't see any disorientation, therefore, the Spent Fuel Project Office people were able to use this data to develop this interim staff guidance document that they issued last summer.

All this data is useful for model

development, computer code benchmarking. The French have a model. Pacific Northwest has a model. EPRI has a model. Maybe other people have them. As I say, it appears this creep rate is about comparable -- some were higher, some were lower -- but what are some of the questions? Has radiation damage saturated? The model has a parameter and the question is, well, at some level of fluence, does that parameter go to 1? At these high temperatures, 400 degrees C, you might expect annealing of the radiation damage. And it appears that even with high hydrogen, as long as the circumferential orientation of those little hydride platelets stays circumferential, it doesn't have any effect on failure. In this case, the Surry rods were Westinghouse cladding. The Robinson rods were Seimens cladding.

I was going to show one picture here just so you could sort of see.

(Slide)

This was the Surry. This was the assembly I showed earlier. So we took rods out of the middle here, so these are the ones that probably saw the highest temperature in this assembly, and you can see these are the little grid spaces, and I don't think, as Bob Einziger said, there's no constraint of these.

The bundle is not locked in at all in that direction.

MR. LEVENSON: Mike?

MR. RYAN: No questions now.

MR. GARRICK: What can you summarize for us that the characterization program has provided in the way of additional insights into the long-term performance of the fuel assemblies in a repository environment?

MR. SCOTT: I think the thing that we know is that at least for the rods we've examined, we didn't see any unusual behavior on the cladding ID. None of these rods had any breached gas release, extra gas release did not occur during the storage. The amount of creep capability seems to be much higher. A couple of years ago everybody was predicting 2 percent would be the creep strain failure limit. Well, we've gone in several samples well past 2 percent.

There's another program they're talking about -- these irradiation effects sort of go on with burnup. There's a rim that develops on the outside of the fuel -- if I can go back -- this one maybe doesn't show it too much.

(Slide)

You get a lot of gas buildup and very

small grains in this area, and there's -- the plutonium is built up here, so the power in this edge is a little bit higher, even though I still have a radial temperature profile. But it doesn't appear that even though we see these sort of fission products moving out toward the cladding, no evidence of damage.

MR. GARRICK: One of the things that you seem to be showing is that there does not seem to be any particular threat to their integrity of the type that we would worry a great deal about from a disposal point of view, as a result of excessive burnup. In other words, it appears that there's considerable margin.

MR. SCOTT: That's right. We haven't discovered anything new that would really degrade that margin. And it does appear that these rods -- I think that to say that, well, they're going to stay intact for some period of time in the cask or maybe in a repository, I haven't seen any measurement evidence that shows that there's some mechanism that's going to make that go away.

MR. GARRICK: Because a lot of the plants are now talking about higher burnups.

MR. SCOTT: Yes.

MR. GARRICK: The other thing that I

wanted to ask about is the fuel assemblies have gone through some design changes with time. Are you able to make any kind of connection between what you've seen and what the design changes might impact in terms of such issues as hydrogen generation and hydrogen migration and creep and the other parameters that you've looked at in your characterization program? Have the design MODs that have been going on addressed any of those, or would have any impact one way or another?

MR. SCOTT: Well, they might. What's different about the modern PWR cladding is it has niobium in it, and its corrosion is much less. So when I showed 100 microns of oxidation thickness at the end of life, these other claddings that have niobium may only have 40 or 50 microns at end-of-life. Therefore, their hydrogen contents will be substantially less.

I'm not familiar with -- I think there are creep -- the French have made creep measurements on the zirconium/niobium alloys, and I haven't heard of any differences. Creep turns out to be -- I don't know whether to call it a strange animal or not -- but I showed it's a function of temperature and stress, but it also seems to be a function of the way they

make the cladding, the chemistry of it, so that even though the Westinghouse and the Framaton cladding have niobium in them, they are different. I wouldn't be surprised if they had substantially different creep characteristics. They have different creep characteristics in the reactor, but I don't know anything -- there's no evidence that I know of that would say that those type of rods are more propensed to have, say, a lower creep failure limit. I mean, I wouldn't expect, if I did these experiments, to have them suddenly fail at 3 and 4 percent.

MR. GARRICK: Yes. The question is motivated as to whether or not the design changes considered as much as they should the downside effects beyond the actual fuel performance in the reactor. We all know that when design modifications are made, there's much more emphasis on the benefits it would gain than the downside effects that might take place beyond the use of the fuel for its primary intended purpose, namely, in the reactor.

MR. SCOTT: I'm noticed in interacting with NRR, they are beginning to think about when they review and approve the fuel behavior in the reactor, what about later on when it goes in the cask, you know, are there any aspects we ought to worry about

now to do that.

MR. GARRICK: Did you do any characterization of damaged fuel?

MR. SCOTT: No. None of these rods had any leakers, and they weren't -- I think there has been -- you guys used to do examination of rods that had swelled up with air or something, water leakage, but that's sometime ago.

MR. GARRICK: Now, has this information been of any use in terms of the degradation models that are being used in the performance assessments? Has this had any impact on how they are modeling the degradation of the fuel during its lifetime in the repository?

MR. SCOTT: I can only say that people that have come to our meetings and been in on this program are some people from DOE and their contractor, Eric Seidman. I think they have a model for creep, so they would be taking this data and sort of seeing how their model did versus this data, but I don't know that the NRC TFPA -- TPFA -- has any models like this in it.

MR. GARRICK: Would you say that the characterization program has increased your confidence in the cladding as a barrier?

MR. SCOTT: Yes.

MR. GARRICK: Okay.

MR. BADAHUR: Maybe so, but the way I see, when this program was conceived, it was mostly for license renewal and high burnup sort of issues, and to apply this to a high-level waste repository would be a bit of stretch --

MR. GARRICK: That's what I'm pursuing. I'm pursuing the "so what" question.

MR. BADAHUR: I hear this exchange, but I think to say that you have confidence in the cladding to be applied to high-level waste repository where we are talking about several thousands of years may be a little too premature. This characterization was essentially for the issues related to the license renewal, to high burnup fuel, to long-term storage. Correct me if I'm wrong, but I don't think high-level waste was ever an issue.

MR. RYAN: Maybe a question is -- you know, these are relatively short-term tests for relatively short-term performance questions. Is there a way to extrapolate effectively to the much longer time frames for the repository?

MR. SCOTT: I mentioned that the DOE people might say okay, let me put a specimen in a

furnace at a lower temperature, a lower stress, and let it be in there for two years instead of just six months or nine months, and you're right. The idea was that if this cask was licensed for 20 years and I want to license it for 40 years -- in a part of the program I didn't talk about, they did look at this cask and see if it had any degradation in the cask itself, or the internals, but the rods had not suffered. There's no reason why those rods in the Surry cask couldn't sit there another 20 years. I think the point I'm saying is -- about the repository is, if the temperatures are less, the hydrides are not going to move around, and it's that changing of the hydrides that would be likely to cause degradation even for a long period of time. Now, we think that because of americium buildup, it gives off alphas -- at 10,000 years the rod pressure might be really high.

MR. GARRICK: One of the questions I wanted to ask was how representative do you think of these particular plants and these particular assemblies are of the total inventory of PWRs and BWRs?

MR. SCOTT: The G.E. Limerick rods are, I would say, very representative. They are a modern design. I mean, there's a whole bunch of 8-by-8 rods

with no liners that are in pools, but now almost all these rods have liners. So there's a big batch of rods that will be in the pools in the future, and in the casks, that are this design, this particular fabrication of the G.E. cladding. The Robinson is sort of the old Zircaloy. It had slightly less tin in it, so it's more a modern amount. As I said before, it seems to me that the new niobium claddings are going to be less susceptible to these degradations, if any. The Surry is an older design. I don't know how many of those, and those have all been in the pools a long time. But the fact that we didn't see anything is sort of the good news on that, and I think that's representative of the old '70s and '80s clad.

MR. LEVENSON: Seems to me an important sort of benchmark is the fact that the assumed failure threshold at a couple of percent that you don't find is a significant finding for all uses.

MR. SCOTT: I think so, yes.

MR. LEVENSON: George?

CHAIRMAN HORNBERGER: Again, just a similar line question here. Your results suggest that there isn't any reason that these casks and the fuel can't be licensed for another 20 years for dry-cask storage.

MR. SCOTT: Yes. We didn't see anything in the -- let me just ask Bob -- in the other parts of the program, you didn't find anything that would say you couldn't relicense them?

MR. EINZIGER: Bob Einziger, Argonne. There's a couple very positive things that came out of these tests. One is whatever comes out of dry storage is what's going to go into the repository. And so these tests have shown pretty much what you put into dry storage is what you're going to get out of it, that there hasn't been any significant deterioration during dry storage that they have to account for when they start looking at the performance in the repository.

The second thing is that at least for the last 15 years there's been the question of hydride reorientation under slow temperature gradients as things cooled down, and was this going to be a problem with the cladding. And these tests pretty well showed that under slow cooling, that the hydrides do not reorient, which is also going to be the same case in the repository under a slow cooldown. So, it's effective there. So those are two very positive things.

The other thing is someone mentioned that

these are short-term tests. Creep tests with irradiated cladding are very rare and they don't go very long. So a test that goes six months in this business is a fairly long test. Some of the Japanese tests are only going 30-60 days. And one of the things that we are able to do in this test is look at our data and see that the creep that we were measuring was considerably under what was predicted by the existing codes, which shows that use of those codes for longer-term extrapolation is probably going to give you more creep than what you actually saw.

MR. RYAN: You know, I think that's some of the exciting result, that if somehow you can take these tests -- and I think short and long are relative terms, we think about 10- and 20,000 years as the front end of performance. If we can somehow figure out how to extrapolate what you've done in a productive way to think about this longer-term horizon for the repository, that's a good thing.

MR. EINZIGER: You have two very positive things going for you in this game. One is that temperatures are always decreasing, so things are going slower. And, secondly, most of these physical phenomena that we are dealing with with respect to the fuel rod performance happen to have been on a log

scale which allows you to condense time quite a bit.

MR. RYAN: So are you saying there's a reasonable way to extrapolate for much longer times, or do additional experiments that would get you there?

MR. EINZIGER: I think anything you're doing that's going to try to figure out what's going to happen in 10,000 years is a crap-shoot.

MR. RYAN: How about 1,000?

MR. EINZIGER: What about a year and a half?

MR. ROSENTHAL: This is Jack Rosenthal. Let's get out of a speculative mode and give us some time to think about it and do some non-dimensional analysis and see what the science will support. Why don't we take it as --

CHAIRMAN HORNBERGER: I think the important thing here is, as Sher said, this work maybe was more of interest to people who want to better understand the performance of their fuel and to upgrade their plants for higher burnup and so forth, but I think the thing that would also be very valuable to us would be what lessons have you learned from this whole exercise that would affect the long-term performance of the fuel in a repository environment.

MR. RYAN: I'd add a second thought that

if there is a way to think about how you could take what you've done and bridge it to additional work, it would be helpful in the longer haul. That's a great homework exercise to think about.

MR. LESLIE: This is Bret Leslie, from NMSS Task Group, formerly from the High-Level Waste Program, so maybe I can add a few insights on both how DOE for Yucca Mountain is approaching cladding, and how the NRC has dealt with cladding in their performance assessment code and the TPA code. In fact, we don't take any credit for cladding. DOE has shown various levels of interest in taking credit for cladding over the post-closure period. The container life and source term key technical issue made several agreements on extrapolation and the basis for the DOE's approach for taking credit for cladding.

So, I don't think the NRC has ever said that DOE can't take credit for cladding during the post-closure period, but we're asking those types of questions already of DOE to provide support for their long-term extrapolation.

MR. GARRICK: This gets important maybe only when you are seeking answers to what the real risk is because I would suspect that the real risk is going to be impacted by the cladding performance.

MR. LEVENSON: George?

CHAIRMAN HORNBERGER: Okay. We're good for the next 20 years, and limiting our attention not out to 10,000 years, we're off that. How about 20 years beyond that? I mean, is it fair for me to infer that your results suggest that if you license for another 20 years and somebody said, "Okay, we would like to relicense these casks for an additional 20 or 40 years", there's nothing in your results that would suggest that there is some limit in the next tens of years?

MR. SCOTT: I think we could say that, that it's -- I don't see any mechanism that we've seen, or anything that we've seen that would say that after 40 years it's going to do something different. It continues to cool down. Even if it were to be reconstituted and go back through some heat-up again, I think as long as it didn't go above 400, it would be okay. Now, we may do some experiments where we do that, we'll creep them for a while, we'll take them back and sort of anneal them maybe at a higher temperature, make some mechanical property measurements, creep them again, and see if some temperature excursion would be -- how detrimental would that be because it's the cycles -- if you heat

it up, you dissolve these hydrides, and then when you cool it back down they reprecipitate. If they're under stress, they do then reorient, and that's the basis for some failure.

CHAIRMAN HORNBERGER: Thank you.

MR. LEVENSON: A couple of questions, one a comment, I guess. Fifteen years ago, what you're now calling "medium" burnup really wasn't medium, it was pretty good. But have you observed any at all indication that there might be crack propagation form the pellets into either the clad or the lining?

MR. SCOTT: When we see these little cracks between the two pieces of pellet, does that maybe put a stress on the cladding, and I don't believe we saw any ID cracks in any examinations we've done.

MR. LEVENSON: That's one of the things which there has been a question, is whether there is crack propagation.

MR. SCOTT: And particularly when you get this -- as the burnup increases and you get this compressing between the pellet and the cladding, and these fission products sort of ooze out of those cracks, that might be more likely, but we haven't seen any.

MR. GARRICK: In that connection, Milt, I wanted to insert the issue of unzipping. Unzipping is a phenomenon that's been referenced in some of the analyses that are performed with respect to fuel behavior. Have you seen any -- and this is really asking a similar question, the same question -- but have you seen any evidence that the unzipping phenomenon could be an initiated.

MR. SCOTT: This happens in reactor --

MR. GARRICK: No, I'm talking about in --

MR. SCOTT: Bob might know -- I think he did some work in that area.

MR. EINZIGER: Ten-twelve years ago. If you're in an oxygen atmosphere, which is not the case in these casks, but if you had a failed gas or you were in the repository, and your temperature was high enough, being over 250 degrees C for any substantial length of time, you will unzip the rods end-to-end, oxidizing the fuel stressing the cladding and unzipping it.

MR. SCOTT: You have to have a failure first, though, right?

MR. EINZIGER: Yes, you need to have a cladding failure first. You won't unzip it without the cladding failure. Even at lower temperatures, you

will eventually get to the point of unzipping it, it will just take much, much longer. It's a time/temperature phenomena. But once again, you need to have a cladding breach to start it. There has to be a way to get oxygen into the fuel and oxidize it.

MR. GARRICK: Thank you.

CHAIRMAN HORNBERGER: In kind of relation to that, the pictures that you showed of the growth, the bulging, what have you, was at a cross-section, but you made measurements along the length of the sample. Was there any significant difference axially?

(Slide)

MR. SCOTT: For this one, you can see these seem to be quite uniform. Now, I didn't bring the figure with me, but in the report there are some figures that turn out -- let's assume that this is the bottom, down deep in the heater, and that the little tube that comes out the top, so this is the top -- so the heat transfer can go this way, so this might be a little bit cooler. So we had some specimens where this cool end and the hotter end did show some deviation. Like I said before, if you have a 5 degree C difference from here to here, you'll see more creep, so that the middle specimen did have fatter end. And I think all those pictures I showed you of the --

let's see if this says it --

(Slide)

-- this is 2 inches from the top, so this is sort of in the middle. What we do have, we do have the measurements at each end, and I think if we went back and looked at all those, in most cases they are quite uniform. In some cases, they -- in fact, we even made a special effort to measure the temperature profile in the furnace and tried to move the specimen farther down in so there would be less temperature gradient. That was an important consideration, yes.

MR. LEVENSON: Do you know for those specimens that had fairly high oxide, by the time you got the sample to a furnace, it had been kind of physically abused. It had been removed from a coffin, had been bounced around, sent into a hot cell, cut up into pieces, et cetera. Any indication that there is significant flaking of this oxide during that kind of handling, even before you start to stress it?

MR. SCOTT: I think we've tried to look at the surface -- and you can sometimes see -- we call it delamination or spawling in the thicker oxide. It will come off, but I'm not -- I don't think anybody has said, "Oh, we got it, here's a place". We don't know what it looked like before, so if there is a

little spot that looks like it's bare, we don't' know when it got bare -- you know, did it fall off, at what point. But I don't recall anybody saying that they've seen those type of phenomena defects or whatever.

MR. LEVENSON: Maybe I should ask Bret rather than you -- do you know, is this information, the fact that there does not appear to be a threshold for early rupture, et cetera, being cranked back into not our 10,000 year issue, but our transportation failure studies, because certainly the timing there, we don't have an extrapolation issue.

MR. LESLIE: This is Bret Leslie again. I'm going to defer to someone from SFPO, and there's no one here. I don't feel comfortable answering that question.

MR. LEVENSON: Well, I would hope that that information does circulate internally because it seems to me that not only the fact that what had been assumed was a creep threshold, if there is one, is significantly higher than originally thought. And, secondly, the fact that under these conditions, hydrogen reorientation has not occurred are both extremely important for our looking at transportation accidents, which are the same time scale as the storage.

MR. SCOTT: The user need we have from them implies that we would try to make some mechanical measurements for this question of transportation accidents. We're not quite sure if we can, on a small Zircaloy specimen, do fracture toughness measurements, but we'd like to make some kind of measurements to help stress the analysis of -- you know, bang the assembly or the rod against the wall or something.

MR. LEVENSON: Let me ask a "have you stop beating your wife" type question. I assume that somebody feels very strongly about your conclusions that there's been zero deterioration in 15 years, otherwise there would be no legitimate reason for using this for a LOCA study, since nobody is going to put it back into the reactor. If there had been any deterioration, it would be very improper to use it for a LOCA study.

MR. SCOTT: Well, the point of it is that the LOCA test -- we've never done any LOCA test on high burnup rods.

MR. LEVENSON: I know. But for old rods, for 15-year rods, it's not the right thing to do --

MR. SCOTT: The Robinson rods that we're going to do the LOCA tests on were never in a cask. They've only been in the pool.

MR. LEVENSON: Ah, okay, I'm sorry, because that wasn't at all clear.

MR. SCOTT: I'm sorry. Only the Surry rods, the medium burnup rods, were in the cask. The Limerick BWR and the PWR Robinson rods were only in the spent-fuel pool, they've never been in a cask.

MR. LEVENSON: But how old are they? How long have they been out of the reactor?

MR. SCOTT: The boiling water reactor rods maybe came out of the reactor in '99. The Robinson rods came out of the reactor in I think the middle '80s, or maybe late '80s.

MR. LEVENSON: So two out of the three -- whether it's in the cask or somewhere else it's a question of the change with time of deterioration. So one of them is a new set of rods. Okay. That wasn't clear to me.

Does staff have any questions?

MR. MAJOR: You mentioned some international work. Do you know what kind of results they're getting? I heard France and Japan. Are they getting similar results, or do you know?

MR. SCOTT: I think the Nupak (phonetic) in Japan has maybe a paper, I'm not real familiar with it, but they've been doing some tests of BWR cladding.

I don't know if it's advanced BWR cladding or older BWR cladding. We could try to find out something about that for you. I don't know if there's any creep conferences coming up in the next year, but ASPM has a Zircaloy conference -- is it next summer, Ralph, in Stockholm? There might be some work there. The Germans -- the Germans have been working on this because they have a lot of fuel that's going to go into casks, I believe, so there's creep furnaces all over the place, and we get different answers. That's the key to me that seems like every different laboratory, for its particular cladding, get a slightly different answer. And the modeler guys keep adding terms to try to take care of some difference that they see in the answer.

MR. LEVENSON: Mike.

MR. LEE: In earlier incarnations of the high-level waste program there was a lot of staff interest in developing a staff position on how to extrapolate short-term data to long-term results. And through probably YMRP development and other process that work on that position just kind of fell over to the side. We should possibly go back and look at the YMRP to see what's in there regarding data extrapolation. And also in the future, in a working

group that we're considering right now, we could possibly explore that issue a little more.

MR. LESLIE: Bret Leslie, NRC staff. In fact, there's an ASTM standard that the NRC staff is participating in on that topic, and Teon (phonetic) would be the appropriate person to talk to about that standard.

MR. BADAHUR: Just of interest, how do you dispose of all the specimens, have they been put back in the cask, or you have to do something else?

MR. SCOTT: I think in the one diagram I showed, there were 12 rods that were pulled out of the Surry cask. Four of them were punctured, the other eight, they just looked at the surface. And I didn't think about looking at that, so there might be some other evidence, photographs of these other rods which would show if there was any spawling or something. Those we think were put back in the assembly. I don't know -- is that cask still out there? Did they put all the stuff back in it at Idaho?

MR. EINZIGER: I think all except for three rods have been put back in. The other three were cut and samples sent out to Argonne East where the rod pieces still remain. There is some sort of Memorandum of Understanding for those pieces to be

shipped back eventually to --

MR. SCOTT: Well, I think we're going to -- I'm going to call it scrap -- some guys might say it's valuable material for research, but it's going to stay at Argonne until Argonne decides what to do -- I mean, there's a lot of stuff. These hot cells have a legacy of chunks of cladding, and they put them in little holes down in the bottom of the hot cell, and put them in little pigs, so that's all going to remain there for now. Then it will be disposed of 20 years from now.

MR. EINZIGER: But in relation to that question, the assemblies were pulled -- when this assembly was pulled out of the basket in that cask, the bottom of the cask was swabbed to see if there was any material, and there was no material recovered.

MR. BADAHUR: Thank you.

MR. LEVENSON: That's an important factor. Staff questions? Anybody else have questions?

MR. MYERS: Could I make -- this is Ralph Myer form Research, and I work with Harold Scott. We have one other observation that wasn't made in this program but I think is relevant, and I'm sitting here deciding whether to mention it or not, and I thought since Harold is running a little early, I'd mention

it. And it has to do with this 400 degree temperature limit which is intended to preclude the reorientation of hydrides after the temperature is high enough to get some mobility. This 400 degree number has been used for a long time as kind of a rule of thumb -- you stay below that temperature and you're okay, you get above it and you're not okay.

I just want to cite a test that was done on a completely different subject. This was a pulse test done on a PWR rod that came out of a French power reactor, and the rod was very similar in its burnup and characteristics to the Robinson rod. Had a lot of oxide, about 100 microns. It was the first specimen tested in the high burnup in the Capri (phonetic) under conditions of a rod ejection accident, a reactivity initiated accident. And the preconditioning in the loop -- this was done in a sodium loop, so it sounds like the conditions are really far afield from what you are really interested in. But the preconditioning was done at a temperature that was intended to be below 400 degrees Centigrade, for the same purpose of preventing the reorientation of the hydrides.

They believed that the temperature soak that they had to go through just to precondition

instruments and get ready for the test was done at 385 degrees. And I don't know what the uncertainty was on the measurements, but 385 was less than 400, and this was supposed to be adequate.

Well, that test, which is the now infamous RPNA-1 test, failed in a very brittle manner at an extremely low energy in the test program. It's the only one that was preconditioned at a temperature near 400. It stayed at 385 degrees for 13 hours. All the rest of the tests were preconditioned at a much lower temperature, down around 300-310 degrees, and did not exhibit this behavior. It was very difficult in going back and looking at micrographs from those specimens, to see any what I'll call macroscopic reorientation of the hydrides. You didn't see it. If you looked very high magnifications, you might look at some small hydrides and say, oh, maybe there's been some -- in other words, the visual evidence that the hydrides were reoriented was not abundant, yet the specimen was embrittled and did behave very differently.

So, I just wanted to mention that because it is an observation that has to do with the 400 degree temperature, and it may suggest that a little more attention should be paid to that particular temperature, and this has to do with just the first

days of storage or the transportation process where you're going through the vacuum drying, and those conditions may subsequently affect the ductility and behavior of the material at lower temperatures where it would normally reside.

MR. LEVENSON: Has causality been established? Do we know exactly why that particular single rod failed?

MR. MYERS: It's a very murky situation, and that has not been confirmed. There is a lot of --

MR. LEVENSON: Are they going to reproduce it?

MR. MYERS: No, they did not attempt to reproduce it. And there's no opportunity to do that in that program any longer. But there is no consensus on the exact causal relation between the hydrides, although a lot of evidence is cited for that occurrence. We have studied this RPNA-1 specimen intensely for several years, and there will never be a full understanding of what caused that specimen to behave in a very different manner than all of the rest. We've never seen anything else like it. On the other hand, no other specimen in test programs around the world have been preconditioned at such a high temperature as that one.

MR. LEVENSON: They've also probably never been subjected to the same kind of asymmetric loading that you get in Capri. That's a little different than pressurizing internally. Banging it in a reactor pulse is a whole separate --

MR. MYERS: That's true, but the result on the cladding occurred before the test, and it made that cladding fracture in a fully brittle manner rather than the typical pattern that we see where you have a brittle failure in the outer rim where that high concentration of hydrides is located, and then ductile tearing on the bulk of the metal. And so regardless of what the load was that caused the failure, the material itself has behaved differently than all of the rest of the specimens, and the most likely suspect is the somehow redistribution of hydrides during that high temperature precondition.

MR. LEVENSON: I think until you have confirmatory evidence -- you know, many years ago, in an experimental breeder reactor, one of the stainless steel hexagonal tubes removed from the reactor, taken into a hot cell, was bumped into something and shattered like a glass bottle. Nobody there could ever reproduce that hundreds of specimens of much higher burnup, et cetera, it was just something funny

or unique about that one. So I think where we don't really have a known causality and we're saying let's pretreat it differently and then it failed, is not -- seems to me this is an important enough issue that -- you don't have to reproduce the experiment in Capri, all you need to do is reproduce the temperature preconditioning.

MR. MYERS: That's right, and I don't know if that's been done. All I'm saying is that --

MR. LEVENSON: It seems to me that would be worth doing in this program.

MR. MYERS: I agree.

MR. LEVENSON: That might be the most valuable experiment you could do with the pieces you have left over.

Any other questions or comments, anybody?

(No response.)

If not, Harold, I want to thank you. Mr. Chairman, it's yours.

CHAIRMAN HORNBERGER: Thank you, Harold. You mentioned your speculation as to whether there were any upcoming creep conferences, and the thought went through my mind, I wonder if people actually put this on their resumes?

MR. SCOTT: I should say we will have a

report. We do have a NUREG CR report that will be out late July-August. It will be printed and available. It's about yea-thick, has all the details of all these measurements and the creep test.

CHAIRMAN HORNBERGER: Thanks very much. I think that we're a bit ahead of schedule. Is there anything that we need to take care of before break, or should we break until our research presentation?

We will go off record and we will resume at 10:45.

(Whereupon, a short recess was taken.)

CHAIRMAN HORNBERGER: The meeting will reconvene, and the next topics we're going to cover are on waste management related research, and Mike Ryan is the cognizant member, so I will turn the meeting over to Mike.

MR. RYAN: Thank you, sir. Our first presentation is from Cheryl Trottier, update on waste management related research. Welcome.

MS. TROTTIER: Thank you. And there it is.

(Slide)

Hopefully I followed the instructions properly today, and we'll see. What I thought I would do is start with a little bit about where we are on

budget space. As you may or may not know, the NRC is currently in its usual yearly budget cycle, so I don't really have firm numbers for '04 yet, I can just tell you what we submitted last year.

The budget has been growing, and I actually want to give some credit to you because I think your interest in the program, your interest in the size of the program, has helped to refocus the attention in the Office of Research, and the last couple years we have had a much more viable program. We have used the prioritization system that the office has developed in a more effective way. I do think that there have been some changes. It is certainly not a huge program, but in relation to other priorities in the office, I think it's getting a fair shot now.

We had a fair number of new starts in '03, which I think are also indicative of the growth of the program because we wouldn't have been able to have as many new starts if the program were truly in decline. And I actually expect we may have a larger budget in '04 than what you see on the slide, but that is what we submitted last year in our budget request, and it was in the President's budget for '04.

(Slide)

The next thing I want to talk about is the peer review a little bit. Again, this was something that you suggested that we would benefit from, and I think it has been very helpful to us. I don't know whether you've seen the document -- I can't remember whether we sent it to you -- this is the peer review, and if you don't have it I can get you copies. It's useful because of two components. It provides the results of the peer review, but it also provides our plan as an addendum to the peer review.

MR. LARSON: It's Allen McGezy's (phonetic) group.

MS. TROTTIER: Yes. We used them because my experience with them on looking at the DOE research program they seemed to be able to acquire people who had expertise in the field that we're working in, and I thought that that would be most beneficial -- and they pay them. Lots of times if you have volunteers, you don't get the same quality because people just have limited resources available. So they make sure they have the people available, that they put the time in, and they do the review. And so I think we got some very good comments from the review.

We are currently in the process of working on addressing those comments. I'll just mention a

couple of the recommendations. One, they felt we would benefit by having a more extensive list of references in the document so that it was clear that we had, in fact, reviewed all the pertinent research in the development of a plan.

And the other thing that they encouraged us to do was to continue to solicit from stakeholders feedback on prioritization, which we will continue to do. We are currently in the process of adding some anticipatory high-level waste to the plan that we will then put forward for this year. I'll talk a little bit about where we're going with that as I progress through this.

(Slide)

Now, the Chair had specifically asked us to kind of give you an overview of the program, and so that's what I'm going to focus on today. A large percentage of our current activities do focus on user need items. Two of the main ones at this point, at least from a resource perspective, are support to rulemakings that are currently underway. One for clearance, and the other one on entombment. And entombment is not a rulemaking that's really made a lot of progress, but really a lot of research components need to be in place before staff really

moves forward, and we are probably a couple years away from a rulemaking there.

So we're currently heavily involved in developing technical bases to support the clearance rulemaking. And at this point I would say from a research perspective, most of that is in survey methodology because you're dealing with materials where the contamination is not necessarily going to be on the surface, so you're going to have to have different techniques.

What we're hoping to do is that that methodology will support decommissioning decisionmaking as well because you often deal with subsurface situations when it comes to decommissioning sites as well. So the methodology will be an extension of that, and actually will hopefully be incorporated into the methodology, which I know you have heard about before, and eventually there will be documentation dealing with subsurface and equipment as well as what we have today in the land contamination issue.

I'll just briefly speak about some of the user need activities. Of course, of high interest are the dose assessment codes that we're using. We are working on an update to RESRAD called RESRAD Off-site.

This is going to be a lot more difficult to deal with than we've had in the past because DOE is in a developmental stage on this also. And if you remember, RESRAD is a DOE code. So NRC has to respect that component of it. It isn't our code, we can't just take RESRAD and make it fit our needs. So we are working closely with DOE to have a coordinated effort so that the ultimate code will be useful to both agencies.

One of the other big activities that we have ongoing as a result of user need requests deals with looking at the food-chain pathway and trying to identify places where the data is weak and where we could update that data to provide more realistic assessments, and that's probably a three or four year project. I was reading the plan actually this morning. It's very extensive, the amount of research that's going to be involved in looking at some of these food-chain issues.

CHAIRMAN HORNBERGER: Who is doing that work?

MS. TROTTIER: PNNL. And they are working with the former Soviet Union and the European Union who have similar activities ongoing. So we're getting a lot of leverage out of that, so I think in the long-

run it will be very beneficial.

CHAIRMAN HORNBERGER: On the previous one you mentioned RESRAD. I've already forgotten the name of your screening code that you --

MS. TROTTIER: D&D. We have a very small effort on making some more realistic assumptions. One issue is the pond. The fish pond has always been a point of contention, so I have a new intern now, who I unfortunately have deflected to other activities, but he will be working on doing some updates to some parameters, and possibly some information that we glean in RESRAD space -- he's turning around looking at the wall now -- but some information we glean from the RESRAD effort we may be able to incorporate into D&D. We will always maintain D&D, but as a screening tool.

CHAIRMAN HORNBERGER: You're maintaining it, but have people picked it up? Is it being used?

MS. TROTTIER: I'm going to defend my staff here, because it's interesting. This is a topic that's asked often. And, in fact, last year I was asked by the Commission this very question, so I did a little survey. This was a real easy survey. I went to Region I. I figured Region I is a big region and reflects the behavior that you would expect in other

regions. And wanted to know how many people were using D&D.

Well, when we first published D&D, a screening table was published in the Federal Register Notice, and although I was adamantly opposed to publishing a screening table because it could be misconstrued as cleanup levels. Nonetheless, it's out there. And roughly 80 to 90 percent of our licensees use that screening table. So the answer is, a lot of people are using D&D. It's only the sites that have big problems, that need specific information, that aren't using D&D. Now, are they using D&D properly? Are they using it as cleanup levels? My guess is yes, but I can't deal with that. But they are using it. D&D is a simple tool. It obviously meets the needs of a lot of people.

Groundwater transport issues -- mostly at this point we're testing strategies. We're testing conceptual model uncertainty, parameter uncertainty, and so we're having kind of a one more contract to look at coming up with a strategy for that.

The last piece I'll speak about briefly, the primer on risk analysis approaches is actually work we've asked the NCRP to do for us. And this goes back to that issue of the differences between the NRC

approach of having a license termination rule of 25 millirem and the EPA view that a risk range of a number that would look close to 15 is better. So, I think by the end of this calendar year the committee should come forward with some report. What we asked them to do was to compare the differences in approach and, if possible, suggest a method for harmonization.

MR. GARRICK: Is that really risk analysis, or is that just deciding what the standard ought to be?

MS. TROTTIER: Well, the question is really the approaches in risk management more than risk analysis, but it's what is a feasible way --

MR. GARRICK: I'm glad to hear that because the NCRP is not known as a bastion of expertise on risk analysis.

MS. TROTTIER: But the goal here -- and we put the last piece as only if they could achieve it. We didn't want them to start down the trying to find harmonization solutions. But we thought if somebody really analyzed how the approaches are done differently, they could maybe find a common ground where -- I'm sure you've been briefed on the MOU. There's not been a great deal of success there, and hopefully maybe there will be some method that they

can come up with. I think they actually had a public meeting up at West Valley, and they have a very diverse committee of people involved in looking at this, so I'm just hoping that that is the case.

MR. RYAN: Isn't it a question of something like 15 versus 25 in the standard kind of also involved in uncertainty of calculations?

MS. TROTTIER: Yes. They'll focus on that issue.

MR. RYAN: Yes, that's kind of a key, I think.

MS. TROTTIER: One of my drivers here in asking them to do it was sometime ago Dave Coker from Oak Ridge talked about his top-down/bottom-up approach, which I liked very much. I think it's a very rational description, and you could almost merge it into a single philosophy that both agencies could use. So he's on this committee, and I'm hoping that these ideas will be discussed and brought forward because I think there are solutions to this problem and, unfortunately, public perception has caused a lot of distrust of both agencies as a result of the differences.

CHAIRMAN HORNBERGER: This is going to be a committee report?

MS. TROTTIER: An NCRP report, a regular NCRP report.

MR. GARRICK: It's not really a primer.

MS. TROTTIER: No. The request was -- actually, the request was for the staff to do it, and I didn't think anything that NRC staff produced would receive the trust of the public because there would be a view of bias after all.

CHAIRMAN HORNBERGER: It's not a primer nor a risk analysis.

MS. TROTTIER: Right.

(Simultaneous discussion.)

CHAIRMAN HORNBERGER: Approaches is good. On approaches is quite appropriate.

MS. TROTTIER: The title comes from the user needs. This reinterpreted the user needs slightly when we went to implement.

MR. GARRICK: Is such a hot-button issue as dose response off the table as a consideration for any research activity?

MS. TROTTIER: Well, I'm going to talk a little bit at the end about some other things we're doing, so maybe -- I'm not sure -- maybe I'll touch on that a little bit.

(Slide)

Then the remainder of what we're doing is primarily as anticipatory work. And the three big areas that I'll focus on there. We have several contracts looking at sorption, and this is follow-on to work that has actually been concluded in '03, so one is with Sandia and the other one is with USGS, and these will be a several-year effort, but hopefully will have some good results at the end. They are working very closely together, so there is good synergy between the two approaches.

We are also looking at groundwater monitoring from a perspective that there will probably be the need for sites to have groundwater monitoring, and we're looking at the various strategies. That's a very recent activity that we just started a few months ago.

And the last piece is we're looking at basically the non-concrete engineered barriers as well because there have been reports from the National Academy in particular about some of the clay covers not holding up over time, and that is not a common tool used in NRC space, but we thought it would be worthwhile to do a little research in that area because down the road that may become more and more of an option.

MR. RYAN: All these are that kind of D&D issue?

MS. TROTTIER: Yes. Our main focus is at this point decommissioning. We talk about it in a generic sense. In other words, most of the work we do does support low-level waste as well as decommissioning, and in some sense some of it you could even say supports high-level waste, but we really tried to focus on decommissioning. Those are the areas where the biggest questions seem to be.

MR. RYAN: And I would guess not only reactor decommissioning, but other NMSS licensee decommissioning of all types.

MS. TROTTIER: Most of the problems actually come from the non-reactors. I mean, the reactors are ont the ones with the long-term, on-site contamination issues.

CHAIRMAN HORNBERGER: I actually find the evaluation of clay covers somewhat surprising, partly because of what you said, that that NRC is not a big user. And second of all, there are boodles of research being done in areas where clay covers are important, so your sister agency EPA supports a lot of this work.

MS. TROTTIER: This is a small effort. I

mean, it's not a big effort, and we are looking at the work of others. We're actually having the Army Corps of Engineers do some work on long-term performance.

(Slide)

What's our future plans? Well, one of the things we're going to do, I'm hoping before the summer is over -- although I realize summer is a bad time to hold a workshop -- is to try and hold a workshop with out stakeholders as we go forward in revising our plan.

The plan will become a living document that every year we will go back into it and solicit input to see if there are new issues that ought to be put on the table, and go through the prioritization. As I mentioned before, the peer review does include a copy of the plan at the back, and it does show how we did the project-by-project prioritization. We may even use the workshop as an opportunity to solicit more feedback on the prioritization scheme. We based it on the office scheme but did it on a project-by-project basis, so we did some make some modification. But as is the case even with the Research Office prioritization scheme, it is a subjective scheme, and there may be better ways to do that.

One of the areas where I think we've

gained a lot is through participation in this Interagency MOU. As the years go by, more working groups are formed. Is it four now, Bill? We have four working groups looking at specific issues, and the main goal of this from the get-go was that we have all these Federal agencies looking in this area, why should they all be doing the same thing and not communicating on a routine basis. So the Steering Committee and the working groups foster an environment where there's a lot more sharing going on than I think maybe we were doing on an ad hoc basis. So we have taken it now that all of our contracts with this group have a task which involves participation in these working groups so that they can actually devote resources to getting involved in the working groups. We actually have the Center for Nuclear Regulatory Waste Research also involved in these working groups, so I think it's a very good effort from the standpoint of leveraging resources.

As I said, we are working on this revision to the plan, and it will include some anticipatory high-level waste research needs. Our plan then is to revise the plan and have a final plan by December so that when we enter the budget cycle for the next year, which is normally a January-February time frame, we

will have done our prioritization so we'll know what new starts we should put as the top items. And this will be an ongoing thing.

I think every year we will just revisit the plan in roughly the same time frame. We'll try to build a peer review process into it, maybe not every year, but on some frequency where we'll peer review. Once it starts to get too far out of line of what it was, since many of these research projects last three or four years, you're not going to have a total redo every year of research. And I think it will make it a lot easier for us to be able to assess whether we're meeting our customers' needs.

I will say my one big issue remains making sure that I get the customers involved, and that's one reason we're trying the workshop approach this year, that sometimes when it's just a formal memo that goes out "provide us your comments", you don't always get the full range of comments, and a workshop is often an environment where ideas can be generated more freely, and that's what we're hoping for.

(Slide)

Now, Mike did ask that we talk about this issue a little bit, and I think what I will do is tell you a little bit about the history of an item that's

in our budget, which is called Validation of Health Effects Models. This came about as a result of a project which we've really finished up now. I would say we finished up in failure even though we suspected at the beginning failure might be the outcome, which is the -- see if I can remember its actual name -- it's Joint blah, blah, blah, blah -- I'm having problems with that, but anyway it's JCCRER, which stands for --

MR. RYAN: Joint Coordinating Committee for Radiation Effects Research.

MS. TROTTIER: That's right, Radiation Effects Research -- I was having so much trouble with the two "Cs". This was started after the breakup of the former Soviet Union, and the Department of Energy has put a lot of money into this work, and it is looking at trying to reconstruct some of the doses that were received in the former Soviet Union, particularly at the Miyak facility. These were doses received in the '40s and '50s. And it was always a question about getting access to the data and how good the data was.

So after trying for roughly four or five years we have allowed the contract to expire, which was this year. It actually expired last year, but we

extended it about six months. We ended up only getting some data on acute effects which we will give to Oak Ridge to put in the REACTs database so that when there are acute incidents, then they have a little more data. It's not much for the large sum of money that we paid for it, but we always knew from the very beginning, the Commission told us "You have to re-evaluate every year, don't just give them money", and we did, every year we re-evaluated. And when we got to the fourth year we made the decision that we needed to just call an end to it. But the goal -- see, the original goal was that it was going to validate the health effects model in MAX, which it's not going to accomplish that.

So we're probably going to change the name of that activity, but one of the things that's come up recently -- and I don't know how much you've heard about it -- but it is the vulnerability assessments for the power plants, and we of course use MAX as the code to do those estimates. MAX is a very conservative code. Of course, the reason is because it's based on the linear nonthreshold hypothesis.

We're currently in the process of upgrading the MAX code in many areas, to make it more realistic, but I don't think at this point we can

eliminate the assumption of the linear model. We have efforts going on outside of NRC both at the National Academy through the BR7 committee, which I believe in '04 their report is due out. I'm not expecting any big change here. I mean, the risk number could be changed a little bit, but it's not going to be dramatic.

I think that other work is going to be completed in a few years. We have a huge project at the Department of Energy looking at low-level health effects, which is a ten-year project. So we're a long way from solving that issue. But what we are working on with codes like MAX is the issue of collective dose because that is a regulatory decision tool, and what we're going to be doing this summer is coming up with some recommendations on when you should be using collective dose, how low should you be going to look at collective dose because, of course, one of the big issues is it's not real dose to real people, it's often very small doses to very large numbers of people. So we will be probably making changes like that.

We're also going to be -- I have told NCRP that I was doing this, and I have to get busy and do it -- but we're going to ask NCRP to look at this

issue. This is a good issue for them to look at -- what's the role of collective dose? What should the role of collective dose be in decisionmaking? I'm sure you're aware that the International Commission is looking at making revisions to their recommendations on radiation protection in roughly the '05 time frame, and the role of collective dose is one of the issues that they are tackling. So I think that for the near-term that's a simple thing that we can do.

When it comes to looking at dose response in most aspects we don't have the funds to really look at that in enough detail to help the Agency. The program at DOE is certainly capable of doing that. It's $200 million. That's a huge resource commitment. And whether it gets committed all the way through the whole ten years will be amazing, but they are looking at cellular level which is where you're going to have to look.

We can't at this point identify any group where you can do an epidemiology study that would have any usefulness because we are looking at such low levels. So I think for the time being we're going to focus our efforts on simple tasks that can be accomplished without huge resource commitments, and at this point, at least in the area of these dose

assessment codes, I think we can look at parameters. We can look at the role of collective dose. But the actual risk co-efficients are going to be a few years out.

MS. TROTTIER: That makes a lot of sense, Cheryl. I think that if you look at the Hiroshima and Nagasaki studies that JCCRER did -- I mean, they are still doing them and they are 50 years out. So looking for a lot of low-hanging fruit from the Russian studies may be optimistic.

I do think it's real important and interesting work, and it will probably bear a lot of fruit as the years go by. They are up to something like 140-or-so peer review publications on various aspects of dosimetry and epidemiology. They also have some interesting things emerging like David Brenner's work at Columbia University, on genetic markers for various -- as bio-dosimeters and things like that that will be real interesting to see. But focusing on the practical problems of what I do with collective dose and how do I make a better calculation is terrific.

On collective dose, are you going to address its use not so much as a dosimetry tool, but as a decisionmaking tool for assessing technology? I mean, I think about collective dose in the workplace,

whether it's a work activity where I'm going to predict -- pick a number -- 5 person/rem, and I make a judgment if I can make that 3 person/rem with some engineering additions I've done a good job. But when you get out into the environmental arena, and I'm taking what I define as the Pismo-rem, which is the smallest amount of dose you can talk about and still get paid, and then add it up over millions of people, it's a huge number, but it means nothing because it's dwarfed by background and medical exposure and all the rest. So I think NCRP at one point said a dose of a millirem is trivial, but collective dose bounded on that is trivial.

Are you going to include both aspects of how to use it?

MS. TROTTIER: Yes. In fact, I think you're going to see the Commission coming out giving the staff guidance to be doing that because they have several papers in front of them now -- the Part 30 Exemptions Rulemaking Paper -- and these are critical components of decisionmaking in that area. And just from indications that we've had, this is an area of great interest to them, so I think they're going to be telling us to do something about it. They know what the NCRP is doing, and they see that there are issues

in this area in decisionmaking.

MR. RYAN: Thanks. Questions from members? John?

MR. GARRICK: No, I don't think I have any.

CHAIRMAN HORNBERGER: Cheryl, on your looking forward to anticipatory -- some anticipatory research in the high-level arena, one of the things that the ACNW has at least thought, oh, for 15 seconds or so, about is the potential role of the Office of Research in the performance confirmation area. As you know, we're having a workshop in July, and I think Neil said that Tom Nicholson is going to give a presentation on groundwater monitoring, but can you just tell me if that's part of your thinking about the potential for anticipatory research, or how are you going to figure out what you want to get into, I guess that's my real question.

MS. TROTTIER: Well, that is a good question, and at this point I've pretty much left the staff to generate some ideas. I haven't polled them lately and asked them to produce some, but it's pretty close because sometime this summer I need to see them. But I think that that's a valid place for us to get involved. And so I'm hoping that that is one of the

items that they are paying attention to.

CHAIRMAN HORNBERGER: Well, again, as you know,we have some interest in the anticipatory research aspects, and we'll be interested in keeping abreast of things as they move forward.

MR. RYAN: Milt?

MR. LEVENSON: We heard a presentation earlier this morning which turned out to be a great deal of interest to us, on a subject which originally wouldn't have been relevant. I mean, the idea was related to dry-cask storage at reactor sites and so forth. But, in fact, there's a big area of overlap between information like that for that purpose, and its application both as starting point for Yucca Mountain, and maybe more importantly to potential shipping accidents, et cetera. And I'm just curious -- I mean, none of us really knew that was going on. Are there other things in research that might have been originally started for another purpose and so we weren't informed of, but because it has application that maybe we really should be informed of.

MS. TROTTIER: I doubt there is, but you know what I'm going to suggest when my poor Office Director returns form travel is that I think it would be good for once a year for him to come and brief you

on all the activities we're doing in the waste arena because I come a lot, and that's all you really probably hear about, but in fact the waste arena does cover other issues now besides the radionuclide transport. So I think it would be probably helpful to you to hear from him because he can give the office perspective on those areas that we're engaged in. It is not a big program. I mean, by and large, outside of the dollars that we're spending on package performance, there are not a lot of projects, but it is bigger than the environmental component that you normally hear about.

MR. LEVENSON: The second question I had is for purposes of your part of the organization, how do you identify the stakeholders that you will be inviting to your workshop?

MS. TROTTIER: Well, what we're going to try to do is to start with an internal workshop amongst the licensing staff, which I believe is our primary stakeholder. And if we can, we'll probably hold either a separate workshop or follow-on workshop where we invite -- just a regular public workshop and invite -- particularly it's an opportunity to invite the States because the States have one drawback in that they cannot easily muster a research program with

the resources that they have individually available to them.

So, low-level waste is an area which has always been a challenge because there are not NRC licensed facilities, but while we can't do work that is solely supporting the States, there are lots of generic issues. And so if we hear about those issues, if they have an applicability to a decommissioning situation, there's no reason why we can't look at them in our planning process.

MR. LEVENSON: The first one is an inhouse workshop?

MS. TROTTIER: Inhouse, I believe, initially, and bring in our licensing offices because they are our primary customer.

MR. RYAN: One important question that to me links several of your areas together is the "how much do I leave behind and how much do I dispose as low-level waste" -- I mean, that's a decommissioning question on the one side because you have a residual radioactivity question you have to answer, and then you have a disposal question, is it a pound or a ton or 100,000 tons that have to be disposed. So they aren't very much interlinked, and you're right, I view it to be kind of a continuum of questions, not

separate problems.

MS. TROTTIER: Right.

MR. RYAN: Any other questions?

MR. LEVENSON: Are you really saying that if somebody strikes oil on a site that had an old nuclear facility, don't bother cleaning it up because the oil is going to bring up so much contamination you'll never find the nuclear part?

MR. RYAN: That could be.

MR. LEVENSON: The North Sea now the stuff dumped by Selofield (phonetic) and Kojema from France is a minor fraction of the --

MR. RYAN: Well, we won't go that far. I won't go to a specific case, but clearly Northern Timor is a question that has come up.

MR. LEVENSON: They've recently done a North Sea survey.

MR. GARRICK: I just wanted to expand this question that Milt asked a little bit about, hearing about other programs and sometimes getting surprises. I think that the question extends beyond research in waste. We heard the program this morning about spent fuel characterization. That program was not initiated in the interest of waste so much as just better understanding the conditions of spent fuel.

I'm wondering if there aren't a lot of other things. We know that the nuclear power industry has had some tremendous success in recent years in waste reduction programs, and maybe this committee needs to be more creative in looking at the front-end of this problem and being more aware of what's going on there, and that might include some of the research that's going on for the reactor program, to make sure that we are in the best possible position to offer the best possible advice. I'm not sure we always are.

So when you talk about them coming in and giving us an overview of the research program, maybe we should hear an overview of the entire research program.

MS. TROTTIER: That sounds fine because one of the things that I just thought about as you described that is one of our big issues right now are the new designs, and waste minimization is a component now. And so it will need to be addressed.

MR. GARRICK: Yes. I was very much involved in the generation 4 work, and one of the emphasis there was -- and one of the principal criteria was waste management and waste reduction. And a lot of the activities had to do with way up front, namely, the whole issue of how we design fuel. And so

I think that if we really kind of practice what we preach here of trying to think systems-wise, that maybe we need to be more plugged into what's going on systems-wise.

MS. TROTTIER: I will definitely raise it in that way.

MR. RYAN: Any other questions from staff?

(No response.)

Anybody in the audience?

(No response.)

Oh, I'm sorry. Sher.

MS. TROTTIER: Except for Sher.

MR. LEVENSON: He knows where all the skeletons are hidden.

(Laughter.)

MS. TROTTIER: That's because he put them there.

(Laughter.)

MR. BADAHUR: Just as a matter of clarification, Cheryl, the $3.2 million budget, is that for the total of your branch activity, or just for the radionuclide transport?

MS. TROTTIER: It's the waste arena dollars. That does include clearance and entombment,

but it is waste arena, not -- the rest of it is another million or so.

MR. BADAHUR: So when you do the workshop for the inhouse, the stakeholders, the thrust would be to see what sort of their needs could be in the future, and then you can allocate these kind of funds to them? Would it be possible for you to invite the staff and the Advisory Committee as well?

MS. TROTTIER: I think that the staff and the Advisory Committee would be a good addition.

MR. BADAHUR: Yes, and we would be pleased to be there because by doing so, we will not be able to reflect the members' thinking in some of the work that needs to be done, but also the expertise could be superimposed on that. In the same vein, I was hoping that although Tom Nicholson has agreed to be part of the panel, but if you could encourage your staff to participate in the workshop that the members are going to have on the performance confirmation because in our mind it's a lot larger than just the groundwater issue, and there are a number of inhouse expertise that you have and perhaps resources that you have, that you may want to put into performance confirmation to develop your thinking.

MS. TROTTIER: That's a good idea, we'll

do that. Let me just mention one other thing because while we're talking about this workshop, the workshop that Sher originally asked about, the workshop for our plan, I'm also in the process of developing a research plan for health effects. I should have mentioned that to Mike, but that's another task.

Now, that's a little bit behind because the U.S. Army keeps stealing my senior level for health effects, and it's starting to get on my nerves, but contrary to that -- and I haven't yet asked Donald Rumsfeld to return him -- but we are in the process of developing a research plan now in the absence of our senior level, and the same goal is that we will have a plan in the end of December. And so if the committee would like to hear about that as that plan evolves, I'll make sure that we get on the calendar.

MR. RYAN: Well, as you pointed out, the ICRP is doing a lot, and there's a lot of activity in that area, and that would be great to hear about.

MS. TROTTIER: Okay, we will do that.

MR. RYAN: Just one other quick question and it addresses the kind of safeguards and homeland security type area. We've heard a lot about RDDs and dirty bombs and lots of other things, and in the area of health effects if you looked across 'til you find

this precious little that addresses prompt response and high doses and how one would react to that, we're always dealing with much smaller doses and so forth. Is there any activity in that area?

MS. TROTTIER: Well, I think NSER has had some activity in that area. My suspicion is that Homeland Security is very closely involved with that. And part of the problem is there are so many unknowns on what actually we would be confronted with, but I am sure that -- we have a little bit of RDD work going on in the branch, but it's basically looking at dispersability issues, not the health effects component of it. But I'm sure Homeland Security has HHS involved with helping them on looking at ways to mitigate.

MR. RYAN: I'm sure that will change a lot as time goes by here in the near-term, too. Thanks.

Any other questions, comments?

(No response.)

Mr. Chairman, I'm going to suggest that we take this 2003 ACNW Research Report item and just talk about it for a few minutes. I've gotten some input from Dick Savio on the ACRS report, so I'm digesting those, and I think we've heard some good information today. My suggestion is I come back with

a draft of something between now and the next meeting for us to consider, and we can have that on our agenda. And with that, that would finish what I had to say on this item.

CHAIRMAN HORNBERGER: That was the discussion.

MR. RYAN: Well, I mean, based on the fact I've been out-of-pocket for two weeks, I haven't --

CHAIRMAN HORNBERGER: No, no, I understand.

MR. RYAN: And I'd be happy to have any other input or comments at this point.

CHAIRMAN HORNBERGER: One thing that Cheryl had mentioned that rang a bell with me, this huge DOE program. How long ago was it, two years ago, that we heard a briefing on that? It strikes me that they've been going long enough that perhaps there are some results of research out there, and I wonder if it wouldn't be a good idea perhaps somebody from our staff could, at the very least, poke around on the DOE Web-page and -- presumably these people have annual reports -- and find out what is being funded and whether anything's been produced.

MR. RYAN: That's a great idea.

CHAIRMAN HORNBERGER: And it may be

appropriate at some point to get somebody from DOE, as we had a couple years ago, to give us an update on what they have done.

MR. RYAN: That was part of the LNT workshop.

MS. TROTTIER: Can I volunteer something? Vince does on the side, as a volunteer, keep track of it. So I can check with Vince, and if he has updated information, I could send it to the staff.

CHAIRMAN HORNBERGER: Great, that would be wonderful, thank you. Thank you. That would be good. You know, the briefing that we had obviously, as Cheryl said, this is a lot of money per year for several years, and so the expectations were pretty high.

MR. RYAN: Well, again, I offer the model of the Hiroshima and Nagasaki studies where in the first few years it's not as -- I mean, the real fruit comes later on.

CHAIRMAN HORNBERGER: Yes. Of course, the DOE program -- you probably know it a lot better than I do -- but it wasn't all -- in fact, I think a small part of it was epidemiological, it was really more oriented to research.

MR. RYAN: Well, again, there are some

interesting things, like I mentioned, Brenner's work and other things that would be interesting to hear about.

CHAIRMAN HORNBERGER: Exact.y. So Mike's suggestion is that we are going to -- he's going to pull something together for us, and we don't really have a potential plan for a research report, but is it safe to say that we do plan to have a research report prepared by -- what did Savio say? Last March, probably.

MR. RYAN: I'll have a draft of maybe some input to that for us to consider next time.

MR. GARRICK: Are you asking is there a schedule?

CHAIRMAN HORNBERGER: well, I'm just curious, did we miss -- was March our schedule?

MR. BADAHUR: We have missed the schedule --

CHAIRMAN HORNBERGER: Microphone.

MR. BADAHUR: I didn't want anyone to hear this. We certainly have missed the schedule.

CHAIRMAN HORNBERGER: But knowingly. I n fact, we made a conscious decision to skip this year. And my real question is whether -- we did, we had some discussion and said that we didn't think that an

annual report was appropriate, and we did this with malice aforethought. The question is, do we make this an irregular report and issue it this coming November, or do we wait and issue it in March every other year?

MR. BADAHUR: The way the Commission understands is that we are going to do a periodic review of the research activity with at least once in two years. So you are home free if you do that before the two-year period is up.

MR. LARSON: The health physics section, though, is going to be part of the PCRS report, isn't that what I remember?

MR. BADAHUR: Yes, and I think --

MR. RYAN: I have the draft. Again, I'll pull it all together --

MR. BADAHUR: -- and send me an e-mail to that effect.

CHAIRMAN HORNBERGER: If it were to come together for November or something, that would be okay.

MR. BADAHUR: That would be all right.

CHAIRMAN HORNBERGER: And as long as it's prior to next March.

MR. BADAHUR: The only caution here would be when you go and meet with the Commission, if you

are not planning on saying anything about the research, then it's all right. But if you do wish to speak about that as well, then I would say you may have to --

MR. RYAN: Move it up.

MR. BADAHUR: Yes.

MR. GARRICK: Mike may move this along far enough that we can get it out even earlier.

MR. BADAHUR: It all depends on what you want to do.

MR. GARRICK: Depends on what we want to do.

MR. BADAHUR: The topics you are going to be discussing with the Commission, you already have quite a number of those, and you are not looking for anything more to fill your meeting. So if you don't want to talk about the research program at this time, that's all right.

CHAIRMAN HORNBERGER: Okay. Anything else? It sounds like we are up-to-date.

MR. RYAN: Turn it back to you.

CHAIRMAN HORNBERGER: Okay. What's your pleasure, do you want to break for lunch and reconvene, or do you want to --

MR. BADAHUR: And also during lunchtime I

could have some informal discussion with the four of you in the conference room.

CHAIRMAN HORNBERGER: Okay. So we're going to go off the record now, we don't need the Reporter anymore, so this will be the end of the recorded session.

(Whereupon, at 11:40 a.m., the recorded portion of the meeting was concluded.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Nuclear Waste 143rd Meeting

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Phyllis Young
Official Reporter
Neal R. Gross & Co., Inc.

United States Nuclear Regulatory Commission

EXAMINATION AND TESTING OF SPENT FUEL RODS

By
Harold Scott
Office of Nuclear Regulatory Research

Presentation for
ACNW Meeting
June 25, 2003

Program Scope

- Post-storage characterization of spent fuel rods
  - profilometry
  - fission gas analysis
  - oxide and hydride, hydrogen content
  - mechanical properties (tensile, microhardness)
- Creep testing of fuel rods
- Post-creep mechanical properties
  - tensile
  - ductility
- Medium (≤45 GWd/MTU) and high burnup cladding
- Focus of presentation - testing of PWR (Surry) fuel rods
  - average rod burnup of 36 GWd/MTU
  - rods in spent fuel pool ~5 years
  - rods stored in dry cask since 1985

Regulatory Issues

- License renewal of existing dry casks for storing spent nuclear fuel
  - applications expected as early as 2004
  - cask integrity for continued storage (additional 20 to 100 years) important for safe storage under normal and accident conditions
- Licensing new casks for storage and transport of high burnup fuel
  - power plants to discharge more high burnup (>45 GWd/MTU) fuel
  - spent fuel pools to loose full core reserve capacity
  - timely licensing important for safe storage and transport
- Spent fuel in dry casks must be protected from degradation that leads to gross ruptures (10CFR Part 72)
- Creep and mechanical properties data required for spent fuel cladding in long-term storage
- For high burnup fuel, technical basis required to demonstrate validity of Part 72 requirements

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Post-Storage Characterization

- Profilometry data
  - diameter changes ~0.6%, very little variation
  - thermal creep during storage <0.1%
- Gas analysis data
  - fission gas release 0.4 to 1.0% - within range
  - internal gas pressure ~3.5 MPa - within range
- Metallography data
  - OD oxide layer thickness ~20 - 40 µm
  - hydrogen content ~200 - 300 wppm
  - no hydride reorientation
- Mechanical properties data
  - post-storage microhardness ~240 DPH (no annealing)
  - creep tests
  - tensile tests

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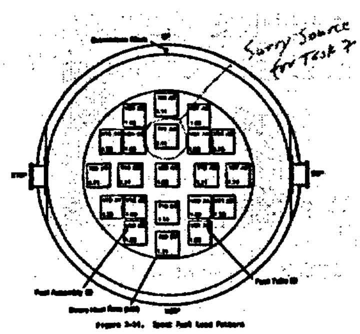
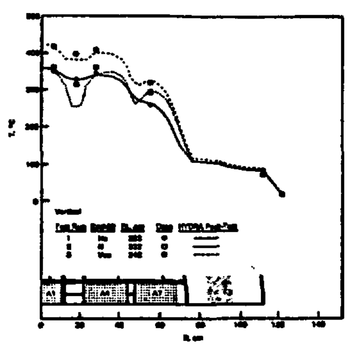
Surry, Robinson and Limerick Cladding Characterization

- Scope of Characterization
  - Fission-gas release
  - Axial gamma scanning
  - Optical metallography
    - Fuel, fuel/cladding interface, cladding corrosion, hydrides, and microhardness
  - Cladding hydrogen and oxygen analyses
  - Microprobe analysis
    - U, Pu, and fission product distribution
  - Isotopic analysis

Surry Cask Storage



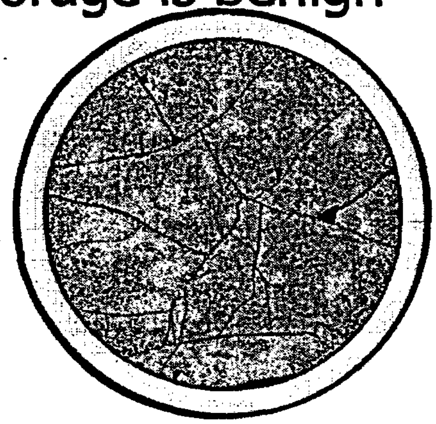
Location of source rods in the Caster-V/21 cask



Peak cladding temperature ≈415°C for 3 days when the cask was in vacuum. Cladding hoop stress, however, was low, <70 MPa.

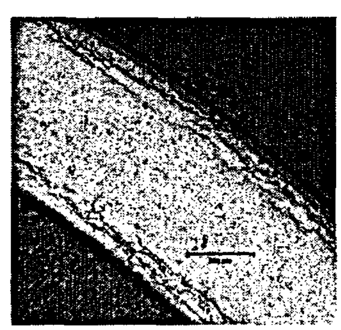
Surry Post-Storage Characterization

- Effect of 15-y storage is benign
  - Gas release: ≈0.5-1.0 %
    - No additional release
  - Fuel microstructure
    - No obvious changes
  - $\Delta D/D_{as\text{-}built}$: ≈-0.6%



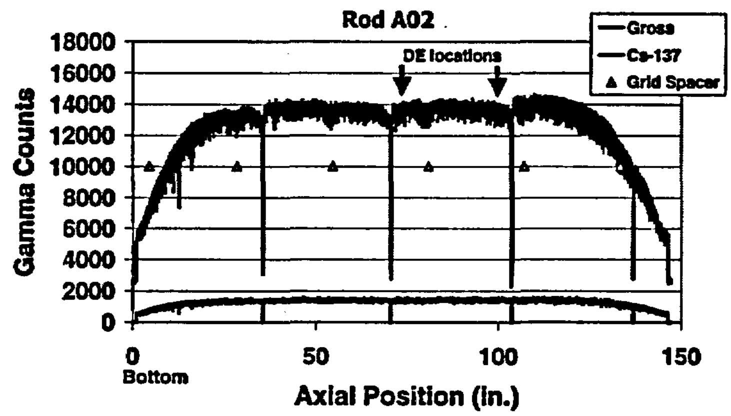
Surry Post-Storage Characterization
(cont'd)

- Effect of 15-y storage is benign
  - Cladding microhardness: 235-240 DPH
    - No apparent annealing in storage
  - OD oxide thickness
    - Normal (≈24-33 μm)
  - Cladding hydrogen content
    - Normal (≈250-300 wppm)



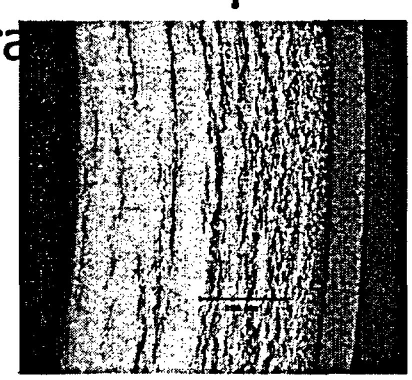
H. B. Robinson Characterization

- As-expected axial gamma profiles



H. B. Robinson Characterization
(cont'd)

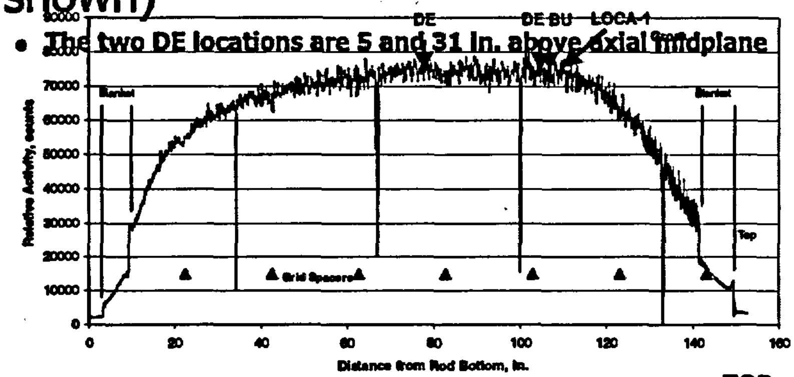
- Increased corrosion and H uptake from high-BU opera
  - **OD oxide thickness: ≈70 µm at axial midplane ≈100 µm at 27 in. above**
  - **Hydrogen uptake: ≈580 wppm at midplane ≈750 wppm at 27 in. above**



27 in. above axial midplane

Limerick Characterization

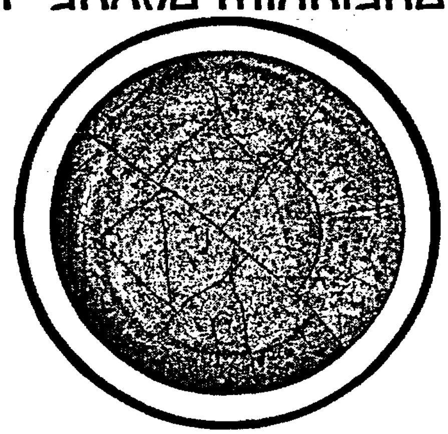
- As-expected axial gamma profiles (Rod F9 shown)
  - The two DE locations are 5 and 31 in. above axial midplane



TOP

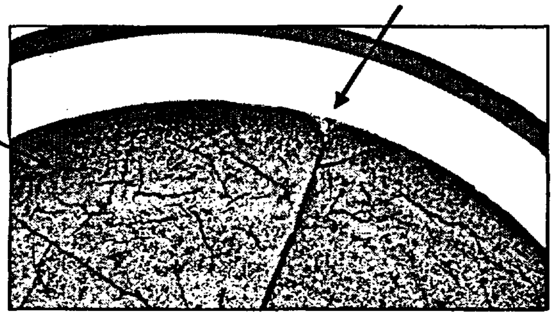
Limerick Characterization (cont'd)

- Rod F9, at 31 in. above midplane
  - Fuel cracking: normal
  - Discontinuous and off-centered "temperature markers" in fuel
    - *F9 was an edge rod*
  - Porous fuel "rim"
  - Numerous fuel



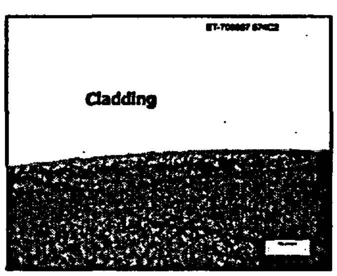
Limerick Characterization (cont'd)

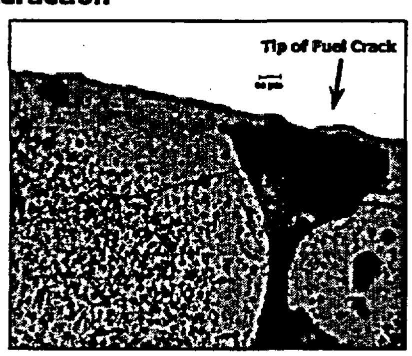
- Fuel microcracks in and near the rim
  - **Formed on grain boundaries weakened by fission-gas bubbles**



Limerick Characterization (cont'd)

- Fuel/Cladding Interface
  - **Tight fuel/cladding bond**
  - **Fission-product deposit in "gap" and at the tips of some radial fuel cracks**
  - **No significant cladding interaction**

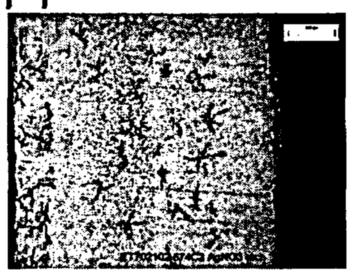




Limerick Characterization (cont'd)

- Hydrides in Limerick F9 Cladding
  - H preferentially precipitated in the low-O Zr liner.
  - Platelets are small, some near the outer surface.
  - Measured H content is low, ≈70 wppm.

Zr Liner ⟶| |



Summary and Conclusions

- **Surry**
  - **Benign effects of 15-y storage in a dry cask (with thermal benchmark tests)**
    - *Excellent overall rod conditions after storage*
    - *Little or no in-cask creep, annealing, or fission-gas release*
    - *No hydride reorientation in cladding.*
  - **Results positive for dry-cask license extension.**

Summary and Conclusions

- H. B. Robinson
  - Low fission-gas release.
  - Tight fuel/cladding bond. No significant fuel/cladding interaction.
  - Max. OD oxide thickness ≈100 μm.
  - Max. cladding hydrogen content ≈750 wppm.
  - Effects of hydrogen on cladding behavior being evaluated in
    - *Cladding thermal creep tests*
    - *Integral LOCA criteria tests*
    - *Cladding tensile tests.*

Summary and Conclusions

- Limerick
  - Oxide and crud layers both thin.
  - H content in cladding low (≈70 wppm), commensurate with the thin oxide layer.
  - Fission-gas release relatively high, possibly attributable to fuel microcracking.
  - Tight fuel/cladding bond. Gap filled with fission products. No significant cladding interaction.
  - Sound overall condition in spite of the high burnup.

Thermal Creep Results for Dry Cask Storage

June 25, 2003

Meeting 21

Thermal Creep Tests

- Presentation Outline
  - Creep testing methodology
  - Creep test results
    - Surry
    - Robinson (vis-à-vis Surry)
  - Summary and Conclusions

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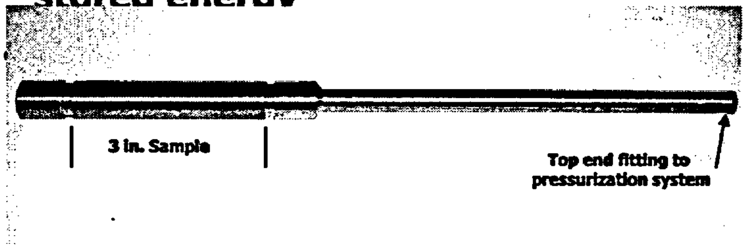
Test Description

- Specimen Configuration
  - 3.0 in. cladding segments, defueled, refilled with Zr pellets, welded ends
  - specimens pressurized with argon gas up to 6000 psi (330 MPa)
  - Pressure regulated to ±10 psi
  - five specimens loaded in furnaces for concurrent creep testing
- Measurements
  - temperature and pressure measured for control
  - diameter measurements at multiple axial and azimuthal locations by laser profilometry
  - length measurements for possible creep anisotropy
- Derived data
  - hoop strain from diameter measurements
  - strain rate from strain-time history

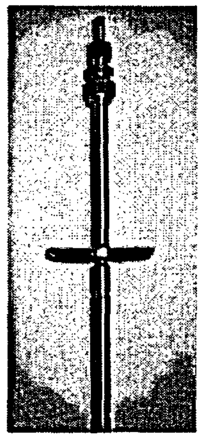
Thermal Creep Tests

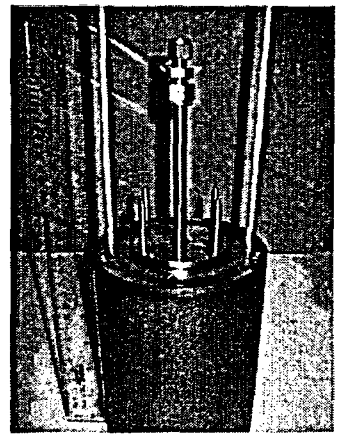
- Creep Test Specimen
  - **76-mm-long segments of defueled cladding**
  - **Cavity filled with Zr-02 pellets to reduce stored energy**



Thermal Creep Tests

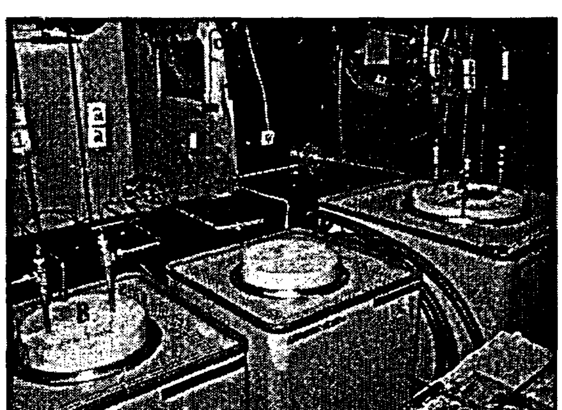
- Test Chamber
  - **Inert-gas purged to preclude sample oxidation during test**





Thermal Creep Tests Furnaces

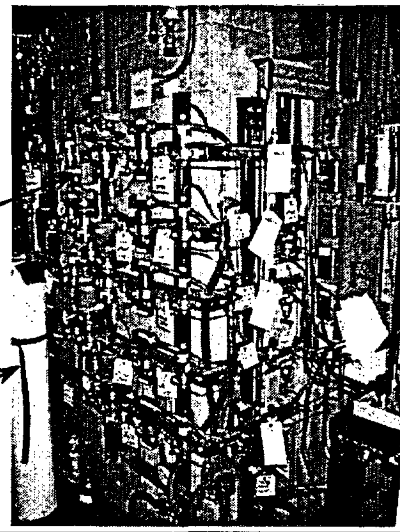
- **One sample each in the 2 small furnaces**
- **Three samples in the large furnace**



Thermal Creep Tests

- Pressurization Systems (5)

CPU-based Pressure Controllers



Penetration into Cell

Gas Cylinders

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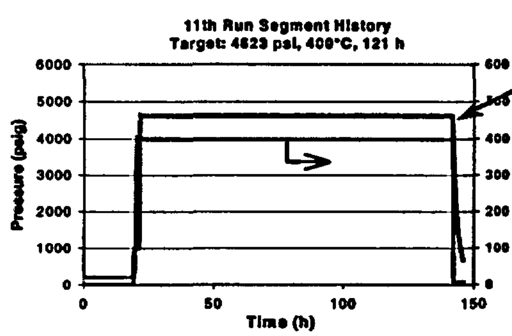
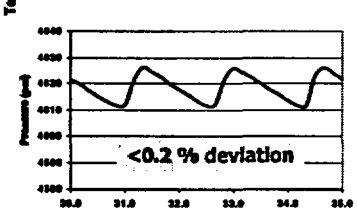
Thermal Creep Tests – Typical Performance

- Good pressure and temperature control
- Periodic shutdowns for dimensional measurements



Depressurized first to preclude hydride reorientation



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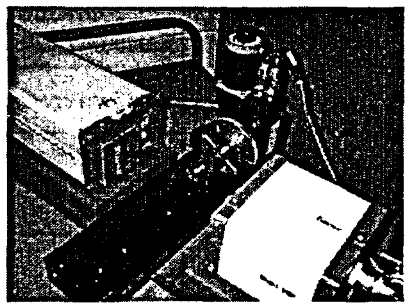
Thermal Creep Tests

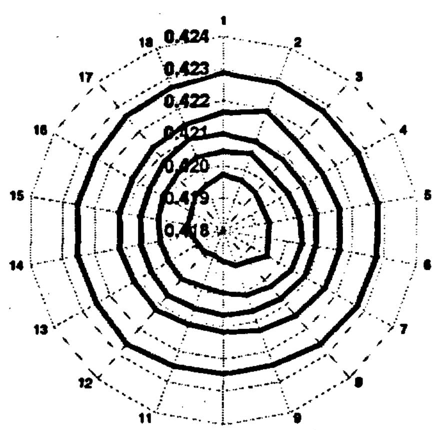
- **Laser Profilometry**
  - Measurements made off-line at room temperature
  - Diameters measured at multiple axial and azimuthal locations to within $\pm 2\times10^{-5}$ in. (0.005% strain)
  - Length measured to $\pm 10^{-3}$ in. to evaluate creep anisotropy.



Thermal Creep Tests

Laser Profilometry – Typical Results

- Midplane cross-sectional profiles of a sample at 0, 335, 671, 1028, and 1820 h.
  (Dimensions in inches.)



Thermal Creep Tests

Surry Test Matrix

	Sample	Temp. (°C)	Stress (MPa)	Purpose
Completed	C3	360	220	Primary/secondary creep
Completed	C6	380	190	Primary/secondary creep
Completed	C8	380	220	Residual creep strain
Completed	C9	400	190/ 250	Residual creep strain
On-going	2-C9	400	160	Primary/secondary creep, ISG-11(Rev. 2)
To be Initiated	*C10*	*400*	*220*	*Residual creep strain, ISG-11(Rev. 2)*

Pioneering Science and Technology

Nuclear Regulatory Commission

Thermal Creep Tests

Surry Summary Results

Sample	Temp. (°C)	Stress (MPa)	At End of Test			Sample Disposition
			Hours	Avg. ε	Intact?	
C3	360	220	3305	0.22	Yes	DE(1)
C6	380	190	2348	0.35	Yes	DE(1)
C8	380	220	2180	1.10	Yes	Bend Test
C9	400	190 250	1873 693(2)	1.03 5.83	Yes Yes	-- Bend Test
2-C9	400	160	286(3)	0.22	Yes	tbd

(1) DE: Destructive examination, for hydride orientation determination. For this, the final shutdown was done with sample pressurized.
(2) Incremental hours
(3) On-going

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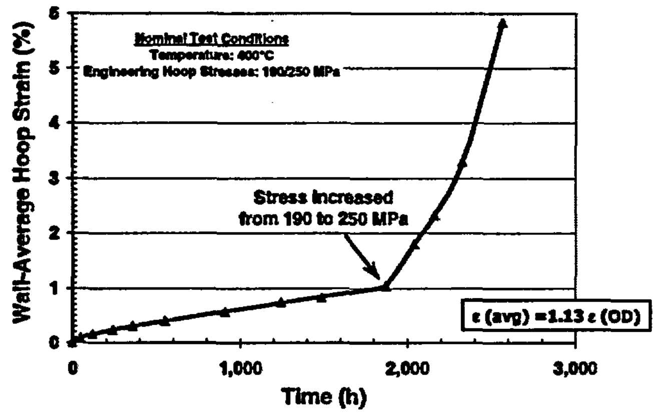
Thermal Creep Tests – Surry C9

- 400°C, 190/250 MPa engineering hoop stress, 2566 h
- 5.8% average hoop strain, no rupture



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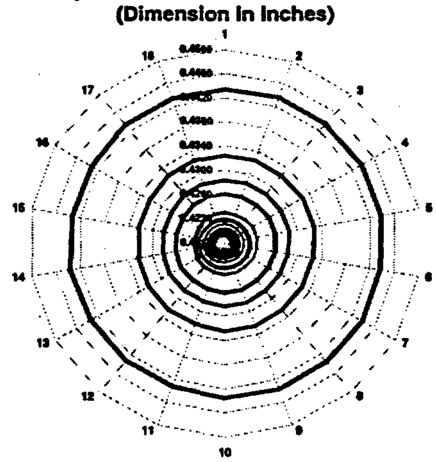
Thermal Creep Tests – Surry C9

- **Deformation uniform even at high strain (5.8%)**
- **No signs of imminent failure**
- **Additional creep ductility likely**

Run-by-Run Cross Sectional Profiles of C9 (Dimension in Inches)



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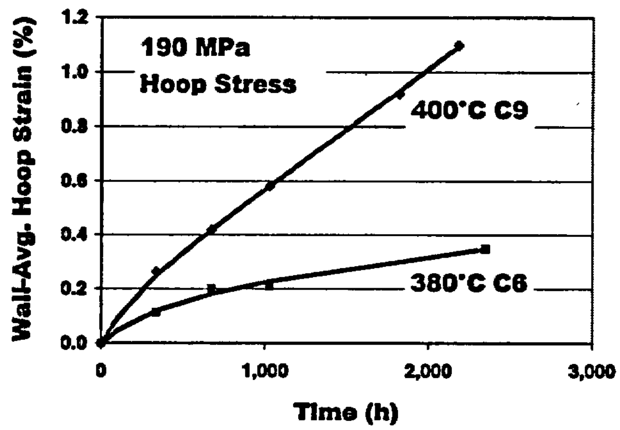
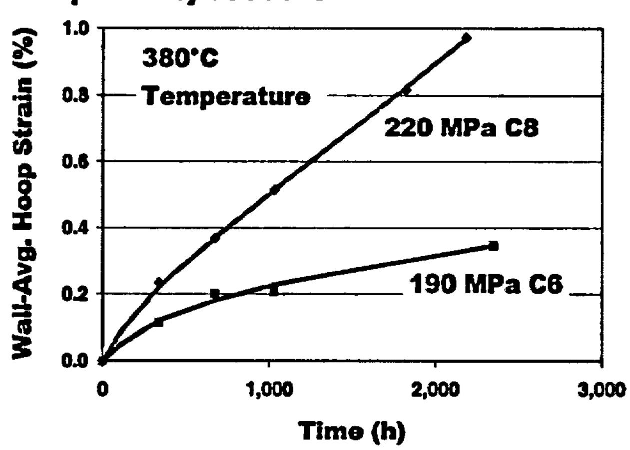
Thermal Creep Tests - Surry

- Temperature Dependency



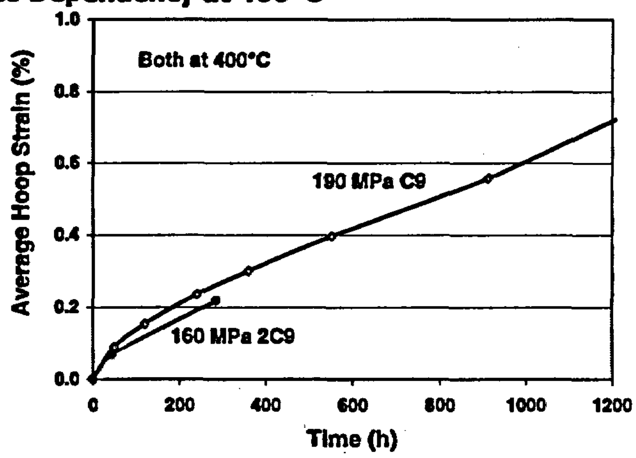
Thermal Creep Tests - Surry

- Stress Dependency at 380°C



Thermal Creep Tests - Surry

- Stress Dependency at 400°C



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Conclusions of Surry Creep Testing Program

- Significant residual creep strain demonstrated for Surry cladding after 15-y dry-cask storage
- Creep data show strong temperature and stress dependency in the regime tested
- Two additional tests at 400°C and 160 MPa and 220 MPa, respectively, to expand the database
- Lower temperature tests for permanent repository applications may also be carried out in future

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High Burnup Spent Fuel Testing for Dry Cask Storage

- Program Scope
  - fuel and cladding characterization
  - isotopic analysis
  - annealing tests
  - thermal creep tests
  - mechanical properties tests
- Cladding Material
  - H.B. Robinson PWR rods: 2 rods (2.9% enrichment, 67 GWd/MTU); one rod (1.9% enrichment, 10% Gd_2O_3, 47 GWd/MTU)
  - OD oxide thickness ~ 60 µm to 110 µm
  - hydrogen content ~ 580 wppm to 750 wppm
- Program Status
  - characterization and isotopic analysis in progress
  - annealing tests completed
  - creep test matrix developed; lead test started
  - mechanical properties testing planned

High Burnup Thermal Creep

- Testing Strategy
  - Conduct two lead tests duplicating Surry test conditions to determine effects of Robinson's higher hydrogen content and fast fluence
    - One of the lead tests has been started
  - Establish test matrix based on lead test results
    - Simple and flexible
    - Emphasizing 400°C
  - Duplicate Surry creep testing techniques
    - Additional systems built

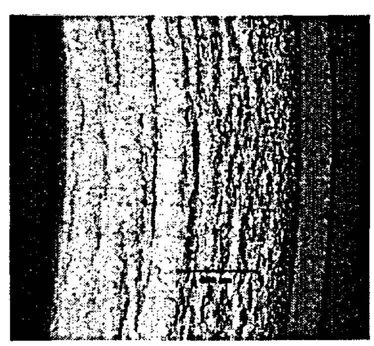
Thermal Creep Tests – H. B. Robinson

Robinson Test Matrix (6/03)

		Stress (MPa)				
		100	160	190	220	250
Temp (°C)	420		1			
	400		1	C14 C15	1	
	380		1	C16	C17	
	360			1	1	
	320					

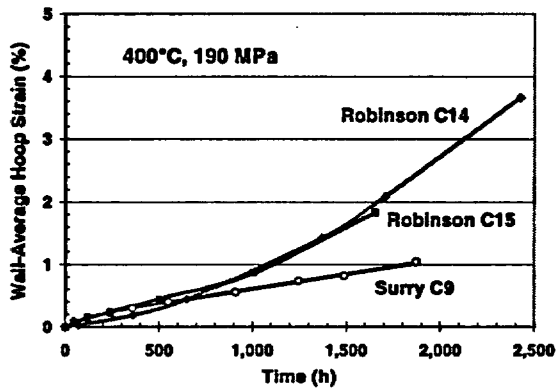
H. B. Robinson Cladding

- Significant corrosion and H uptake from extended operation to high burnup
  - **Oxide thickness:** ***≈100 μm max.***
  - **Hydrogen uptake:** ***≈800 wppm max.***
  - **Hydrides:** ***circumferentially oriented***
- **What are the effects of increased hydrogen and radiation damage on creep?**



Thermal Creep Tests – H. B. Robinson

- **At 400°C, secondary creep rate of H. B. Robinson appears to be comparable to that of Surry at the onset of test. Rate appears to be greater afterwards.**



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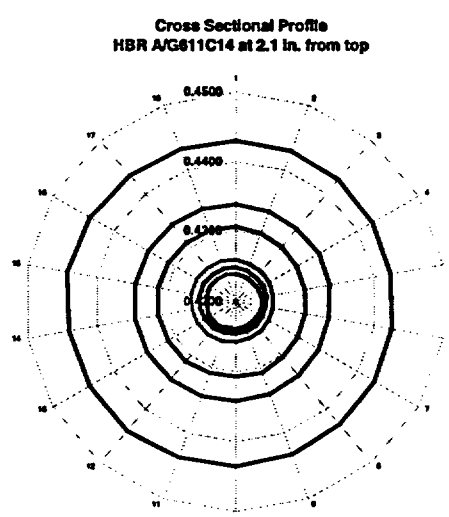
Thermal Creep Tests – H. B. Robinson

Robinson C14 Sample shows good creep ductility: >3.6 % at 400°C and 190 MPa.

- **Max. local strain ≈5.3%**
- **Deformation still azimuthally uniform at end of test**
- **Additional creep life likely**



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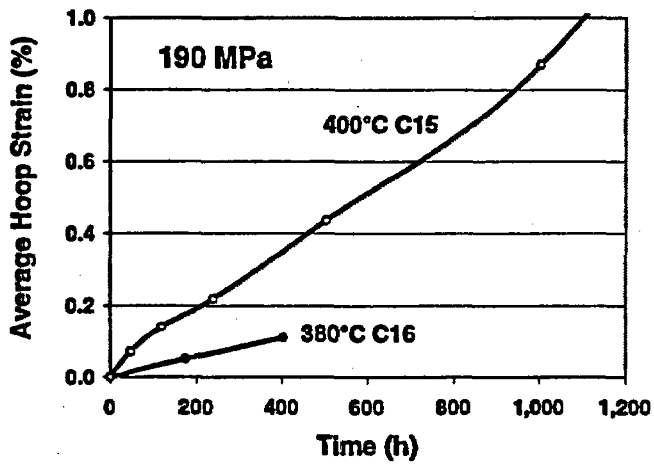
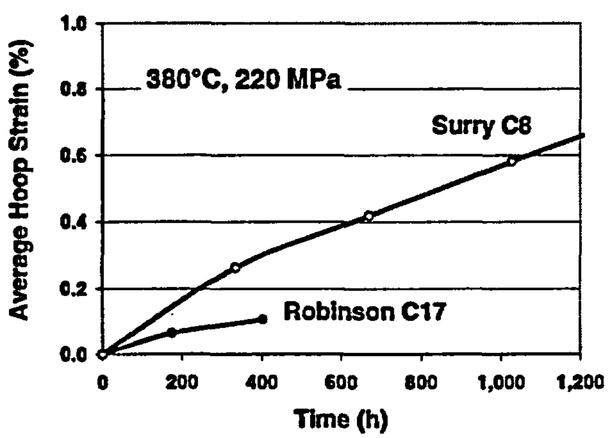
Thermal Creep Tests – H. B. Robinson

- **Temperature Dependency**



Thermal Creep Tests – H. B. Robinson

- **Creep rate of H. B. Robinson appears to be smaller than that of Surry at the lower temperature of 380°C.**



Summary and Conclusions

- **Significant residual creep ductility has been demonstrated for Surry cladding (36 GWd/MTU) after 15 years of dry-cask storage**
  - No hydride reorientation in storage.
  - Findings support NRC ISG-11 (Rev. 2)
- **Steady-state creep rates of Surry cladding show strong temperature and stress dependency in the regime tested**
  - Useful for model development and code benchmarking
- **Early data on Robinson cladding suggest creep rate at 400°C to be comparable to that of Surry, i.e., no detrimental high-burnup effects**
  - Because radiation damage has saturated? Annealing/recovering during tests? Negligible H effect as long as there is no reorientation? Fundamental differences in materials?

Update on Waste Management Related Research

Cheryl Trottier, RPERWMB/RES
June 25, 2003, ACNW meeting

Overview of Program Budget for FY03/04

- Assessment of Doses from Environmental Contaminants
- FY03 Budget - $3.3M and 13.2FTE
- Last year's President's Budget for FY04 - $3.2M and 12.5FTE

Peer Review of Research Plan

- Contracted with Institute for Regulatory Science in 2002 to perform peer review
- Report received early in 2003
- Commended Project Team on several aspects of report
- Provided several recommendations to enhance its usefulness
- Staff incorporating changes to accomodate some of these recommendations now

Program Overview - from Operating Plan

- Several activities address specific rulemaking activities -
  - Clearance
  - Entombment
- Some other activities address user need items
  - Develop and update dose assessment codes
  - Food-chain pathway updates
  - Assess and test groundwater transport codes
  - Primer on risk analysis approaches

Program Overview - (continued)

- Remainder are anticipatory
- Sorption studies
- Groundwater monitoring
- Evaluation of clay covers

Future plans for RTE

- Conduct workshop with inhouse stakeholders
- Continue participation in Interagency Steering Committee on Multi-Media Modeling
- Assess HLW anticipatory research needs
- Revise RTE plan as needed
- Re-prioritize research activities annually for use in budget process

Other related activities

LNTH and Related Issues

- Role of LNTH in dose assessment models
- What's new
- Staff plans for the future