

Official Transcript of Proceedings ACNWT-164

NUCLEAR REGULATORY COMMISSION

ORIGINAL

Title: Advisory Committee on Nuclear Waste
143rd Meeting

PROCESS USING ADAMS
TEMPLATE: ACRS/ACNW-005

Docket Number: (not applicable)

Location: Rockville, Maryland

Date: Wednesday, June 25, 2003

Work Order No.: NRC-967

Pages 1-97

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UNITED STATES OF AMERICA
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

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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

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Opening Statement - Chairman Hornberger

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Spent Fuel Characterization Project

- Harold Scott, ONRR

5

Update on Waste Management Related Research

- Cheryl Trottier, NRC/RES

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

(8:30 a.m.)

1
2
3 CHAIRMAN HORNBERGER: The meeting will
4 come to order. This is the second day of the 143rd
5 meeting of the Advisory Committee on Nuclear Waste.
6 My name is George Hornberger, Chairman of the ACNW.
7 The other members of the committee present are John
8 Garrick, Vice Chairman; Milton Levenson, and Michael
9 Ryan.

10 Today the committee will (1) discuss the
11 spent fuel characterization Project with members of
12 the NRC staff; (2) hear an update on Waste Management
13 Related Research from the NRC Staff; (3) discuss plans
14 for next months ACNW Performance Confirmation Working
15 Group; (4) discuss the committee's approach for the
16 2003-2004 ACNW Research Report; (5) elect ACNW
17 officers for the period from July 1, 2003 through June
18 30, 2004; (6) prepare ACNW reports on recent committee
19 reviews.

20 MR. LARSON: If any.

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

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

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

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

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

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

3 (Slide)

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

23 MR. EINZIGER: Yes.

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

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1 manager of their end of it.

2 (Slide)

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

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

23 (Slide)

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

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1 idea that these fuel assemblies might be shuffled from
2 time to time, maybe they'll be changing casks or when
3 they get to the repository they'll be put into
4 different cans, and so one of the ideas from Section
5 122 of Part 72 was that "fuel during storage will not
6 pose operational safety problems with respect to its
7 removal from storage". So you will have to be able to
8 handle these assemblies, so therefore they need to
9 have some sort of resistance to failure.

10 (Slide)

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

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

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

25 We did make these measurements. What this

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

6 (Slide)

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

9 (Slide)

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

23 (Slide)

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

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

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

12 MR. GARRICK: Where is this work actually
13 performed?

14 MR. SCOTT: At Argonne, Argonne East.

15 MR. GARRICK: Argonne East.

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

19 (Slide)

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

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1 talking about was done at Argonne East.

2 MR. GARRICK: Okay. Thank you.

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

5 (Slide)

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

15 (Slide)

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

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

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1 temperature?

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

6 (Slide)

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

14 (Slide)

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

24 (Slide)

25 So now we can see in this picture more of

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

5 (Slide)

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

13 (Slide)

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

22 (Slide)

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

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

9 (Slide)

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

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

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

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

25 MR. SCOTT: Yes, assembly average.

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

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

6 (Slide)

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

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

5 (Slide)

6 So let me summarize now the Surry and the
7 Robinson and the Limerick. These rods look really
8 good after having been in storage for 15 years. We
9 didn't find any extra gas release or creep, and no
10 hydride reorientation, even though it was up to 400 C
11 at that initial storage.

12 (Slide)

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

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

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1 (Slide)

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

15 (Slide)

16 Now let me go to the thermal creep
17 results.

18 (Slide)

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

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1 hydrogen on these.

2 (Slide)

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

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

17 (Slide)

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

22 (Slide)

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

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

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

11 (Slide)

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

20 (Slide)

21 So these little devices here are the
22 pressure controllers, and in a minute I'll show you
23 some of the curves of the data. So they're 1, 2, 3, 4,
24 5 for the 5 specimens that will be in the -- and then
25 in behind this wall here is the cell where those

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

3 (Slide)

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

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

18 (Slide)

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

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

5 (Slide)

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

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

19 (Slide)

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

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

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

10 (Slide)

11 So here is sort of the results of those.
12 None of them had any failure. They all maintained
13 their pressure boundary. These are the ones that had
14 destructive examination, but we haven't done these
15 bend tests yet. So you can see here we had quite a
16 few hours on some of these. Here's one that got --
17 and I'll show you a graph in a minute -- up to almost
18 6 percent strain at that failure. I think a lot of
19 people would say "Wait a minute, irradiated cladding
20 can't possibly go above 3 or 4 percent".

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

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

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

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

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

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

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

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

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

20 MR. GARRICK: Yes.

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

24 (Slide)

25 In this particular specimen, we had it at

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

8 (Slide)

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

15 (Slide)

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

25 (Slide)

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

9 (Slide)

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

18 (Slide)

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

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

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

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

14 (Slide)

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

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

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

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

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

19 MR. LEVENSON: Well, the 5 percent --

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

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

4 (Slide)

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

14 (Slide)

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

24 (Slide)

25 I think that I may have shown this figure

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

7 (Slide)

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

15 (Slide)

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

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

3 (Slide)

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

9 (Slide)

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

15 (Slide)

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

25 All this data is useful for model

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

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

19 (Slide)

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

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

2 MR. LEVENSON: Mike?

3 MR. RYAN: No questions now.

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

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

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

24 (Slide)

25 You get a lot of gas buildup and very

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

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

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

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

24 MR. SCOTT: Yes.

25 MR. GARRICK: The other thing that I

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

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

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

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

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

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

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1 now to do that.

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

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

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

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

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

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1 MR. SCOTT: Yes.

2 MR. GARRICK: Okay.

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

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

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

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

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

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

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

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

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

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

19 MR. SCOTT: I think so, yes.

20 MR. LEVENSON: George?

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

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

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

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

25 The other thing is someone mentioned that

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

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

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

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1 scale which allows you to condense time quite a bit.

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

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

8 MR. RYAN: How about 1,000?

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

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

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

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

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

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

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

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

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1 MR. LEVENSON: George?

2 CHAIRMAN HORNBERGER: Okay. We're good
3 for the next 20 years, and limiting our attention not
4 out to 10,000 years, we're off that. How about 20
5 years beyond that? I mean, is it fair for me to infer
6 that your results suggest that if you license for
7 another 20 years and somebody said, "Okay, we would
8 like to relicense these casks for an additional 20 or
9 40 years", there's nothing in your results that would
10 suggest that there is some limit in the next tens of
11 years?

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

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

5 CHAIRMAN HORNBERGER: Thank you.

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

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

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

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

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

9 MR. SCOTT: This happens in reactor --

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

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

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

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

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

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

6 MR. GARRICK: Thank you.

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

12 (Slide)

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

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1 let's see if this says it --

2 (Slide)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

9 MR. SCOTT: The boiling water reactor rods
10 maybe came out of the reactor in '99. The Robinson
11 rods came out of the reactor in I think the middle
12 '80s, or maybe late '80s.

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

18 Does staff have any questions?

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

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

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

16 MR. LEVENSON: Mike.

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

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

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

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

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

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

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1 shipped back eventually to --

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

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

17 MR. BADAHUR: Thank you.

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

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

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

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

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

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

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

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

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

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

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

11 MR. LEVENSON: Are they going to reproduce
12 it?

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

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

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

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

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

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

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

12 MR. MYERS: I agree.

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

16 Any other questions or comments, anybody?

17 (No response.)

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

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

25 MR. SCOTT: I should say we will have a

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

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

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

11 (Whereupon, a short recess was taken.)

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

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

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

22 (Slide)

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

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

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

17 We had a fair number of new starts in '03,
18 which I think are also indicative of the growth of the
19 program because we wouldn't have been able to have as
20 many new starts if the program were truly in decline.
21 And I actually expect we may have a larger budget in
22 '04 than what you see on the slide, but that is what
23 we submitted last year in our budget request, and it
24 was in the President's budget for '04.

25 (Slide)

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

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

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

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

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

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

14 (Slide)

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

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

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

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

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

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

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

20 CHAIRMAN HORNBERGER: Who is doing that
21 work?

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

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1 run it will be very beneficial.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

11 MS. TROTTIER: Right.

12 (Simultaneous discussion.)

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

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

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

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

25 (Slide)

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

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

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

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

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

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

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

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

25 MS. TROTTIER: This is a small effort. I

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

4 (Slide)

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

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

25 One of the areas where I think we've

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

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

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

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

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

22 (Slide)

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

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

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

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

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

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

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

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

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1 eliminate the assumption of the linear model. We have
2 efforts going on outside of NRC both at the National
3 Academy through the BR7 committee, which I believe in
4 '04 their report is due out. I'm not expecting any
5 big change here. I mean, the risk number could be
6 changed a little bit, but it's not going to be
7 dramatic.

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

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

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

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

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

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

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

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

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

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

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

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

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1 in this area in decisionmaking.

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

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

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

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

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1 items that they are paying attention to.

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

6 MR. RYAN: Milt?

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

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

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

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

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

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1 the resources that they have individually available to
2 them.

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

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

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

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

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1 separate problems.

2 MS. TROTTIER: Right.

3 MR. RYAN: Any other questions?

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

9 MR. RYAN: That could be.

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

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

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

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

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

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

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

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

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

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

7 MR. RYAN: Any other questions from staff?

8

9 (No response.)

10 Anybody in the audience?

11 (No response.)

12 Oh, I'm sorry. Sher.

13 MS. TROTTIER: Except for Sher.

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

16 (Laughter.)

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

19 (Laughter.)

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

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

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

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

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

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

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

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

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

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

20 MS. TROTTIER: Okay, we will do that.

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

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

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

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

18 Any other questions, comments?

19 (No response.)

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

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

5 CHAIRMAN HORNBERGER: That was the
6 discussion.

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

9 CHAIRMAN HORNBERGER: No, no, I
10 understand.

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

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

24 MR. RYAN: That's a great idea.

25 CHAIRMAN HORNBERGER: And it may be

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

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

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

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

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

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

25 MR. RYAN: Well, again, there are some

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

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

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

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

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

17 MR. BADAHUR: We have missed the schedule
18 --

19 CHAIRMAN HORNBERGER: Microphone.

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

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

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

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

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

13 MR. BADAHUR: Yes, and I think --

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

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

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

21 MR. BADAHUR: That would be all right.

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

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

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

5 MR. RYAN: Move it up.

6 MR. BADAHUR: Yes.

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

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

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

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

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

21 MR. RYAN: Turn it back to you.

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

25 MR. BADAHUR: And also during lunchtime I

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

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

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

9
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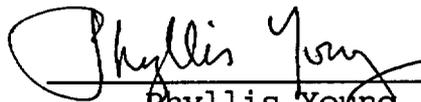
Nuclear Waste

143rd Meeting

Docket Number: n/a

Location: Rockville, MD

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Phyllis Young
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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

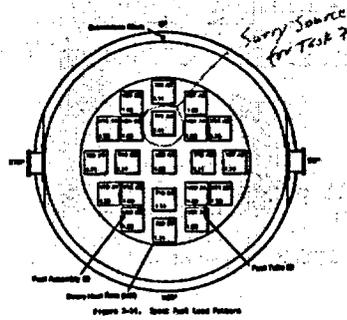
● Scope of Characterization

- 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

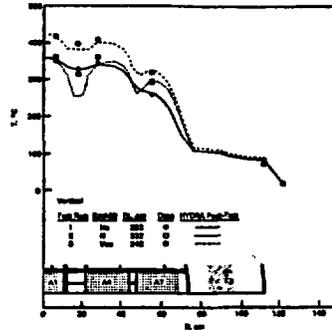
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Surry Cask Storage



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



Peak cladding temperature $\approx 415^\circ\text{C}$ for
3 days when the cask was in vacuum.
Cladding hoop stress, however, was
low, <70 MPa.

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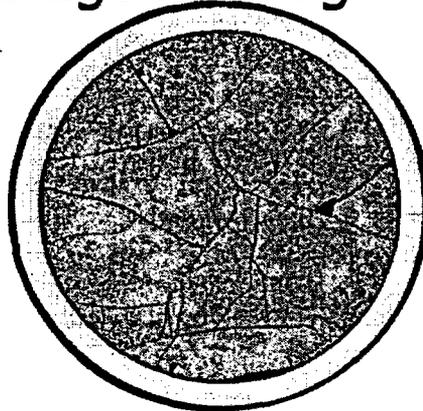
Surry Post-Storage Characterization

- Effect of 15-y storage is benign

- Gas release:
≈0.5-1.0 %
 - No additional release

- Fuel microstructure
 - No obvious changes

- $\Delta D/D_{as-built}$: ≈-



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Surry Post-Storage Characterization

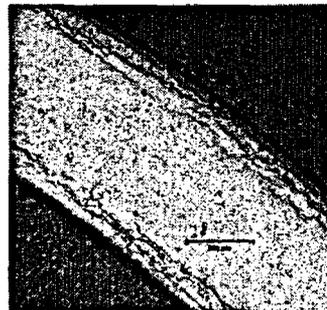
(cont'd)

- 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



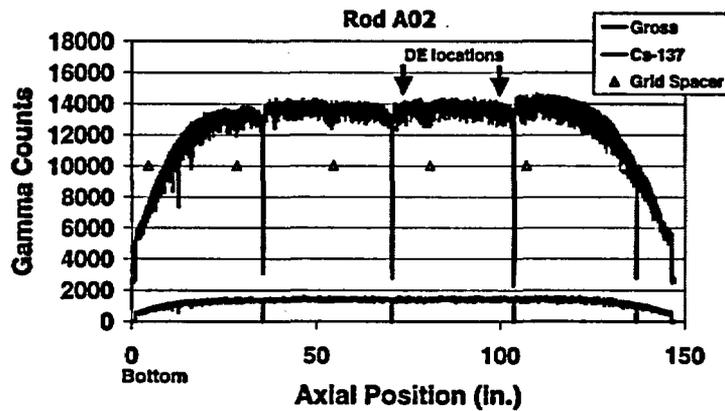
Normal (≈250-300 wppm)

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H. B. Robinson Characterization

- As-expected axial gamma profiles

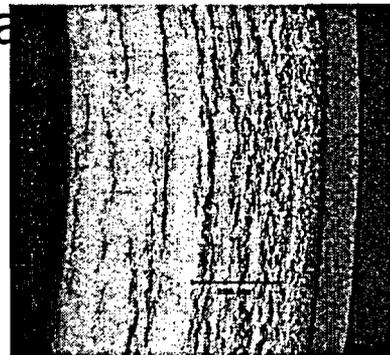


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H. B. Robinson Characterization (cont'd)

- Increased corrosion and H uptake from high-BU operation
- 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



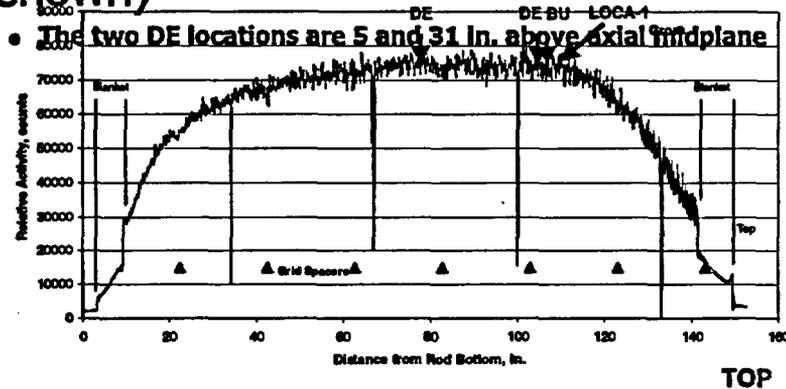
27 in. above axial midplane

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Limerick Characterization

- As-expected axial gamma profiles (Rod F9 shown)

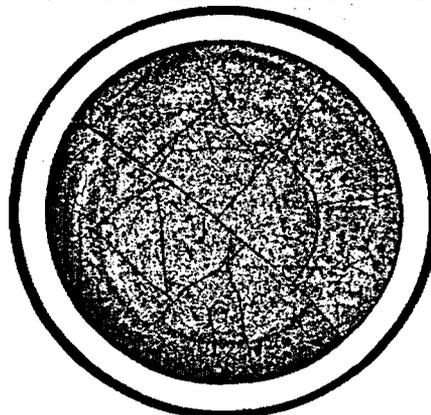


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Limerick Characterization (cont'd)

- 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

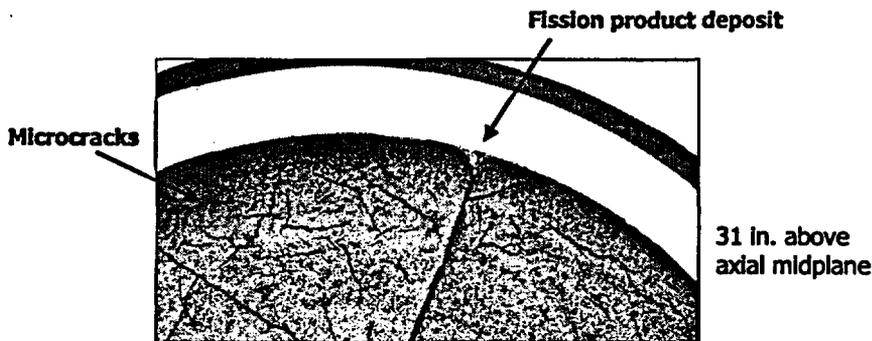


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Limerick Characterization (cont'd)

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

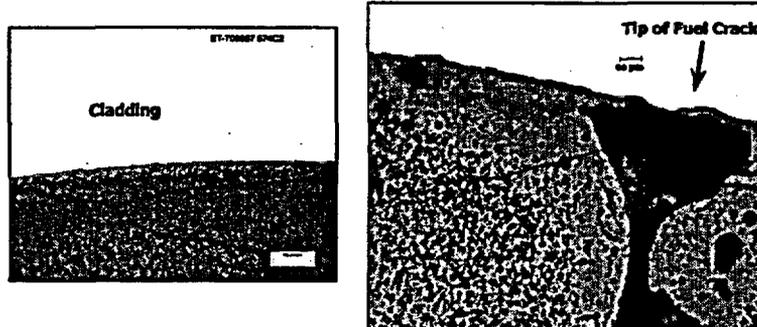


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Limerick Characterization (cont'd)

- 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

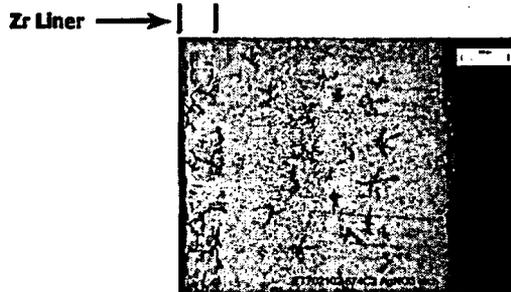


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Limerick Characterization (cont'd)

- 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.



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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.

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Summary and Conclusions

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

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Summary and Conclusions

- Limerick
 - Oxide and crud layers both thin.
 - H content in cladding low ($\approx 70 \text{ wppm}$), 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.
-

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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**

Test Description

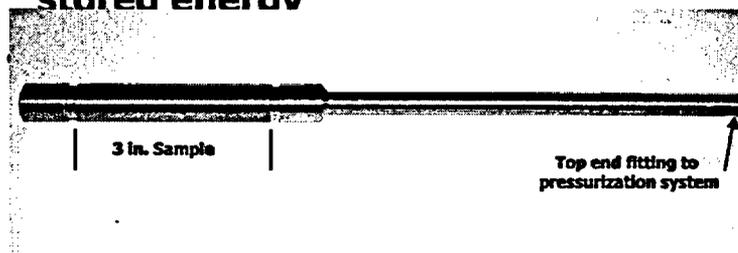
- **Specimen Configuration**
 - 3.0 in. cladding segments, defueled, refilled with Zr pellets, welded ends
 - specimens pressurized with argon gas up to 6000 psi (330 MPa)
 - Pressure regulated to ± 10 psi
 - five specimens loaded in furnaces for concurrent creep testing
- **Measurements**
 - temperature 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

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Thermal Creep Tests

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

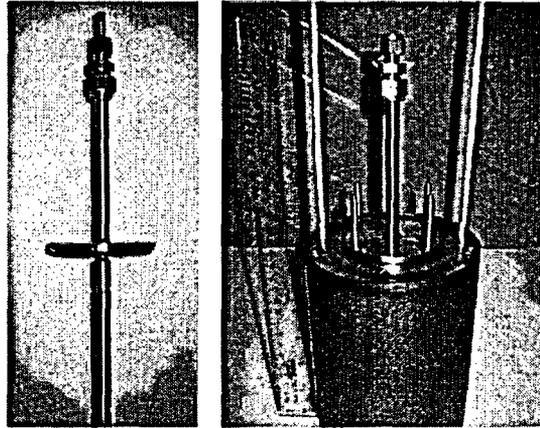


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Thermal Creep Tests

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

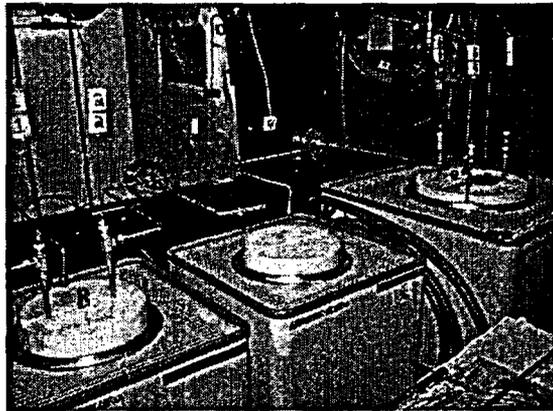


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Thermal Creep Tests Furnaces

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



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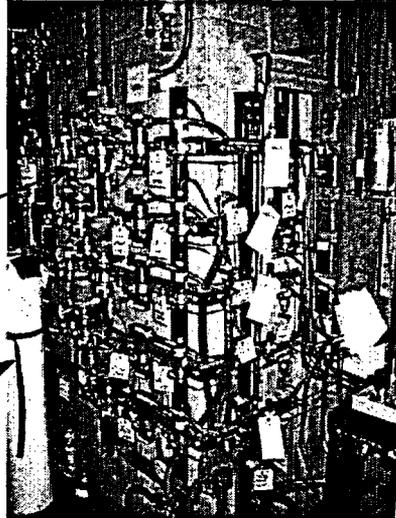
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Thermal Creep Tests

- Pressurization Systems (5)

CPU-based Pressure Controllers

Gas Cylinders



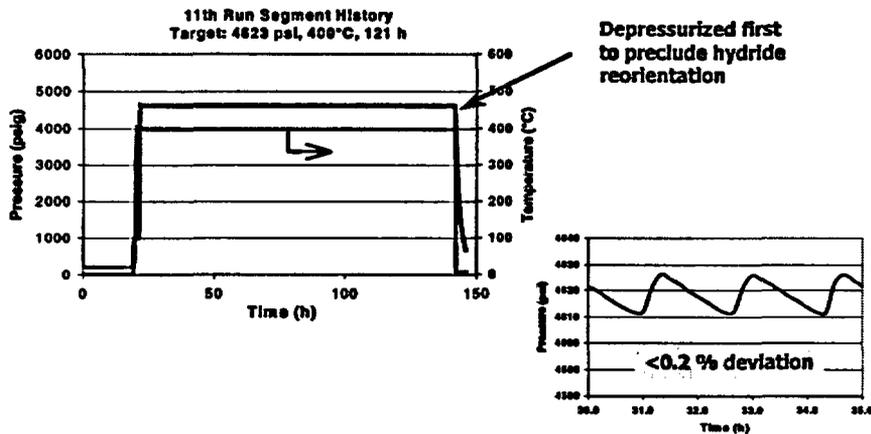
Penetration Into Cell

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Thermal Creep Tests - Typical Performance

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



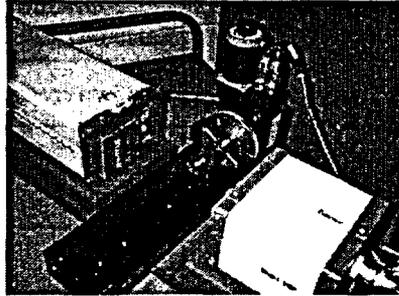
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Thermal Creep Tests

- **Laser Profilometry**

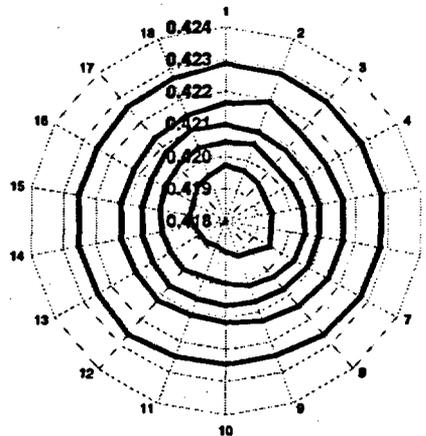
- Measurements made off-line at room temperature
- Diameters measured at multiple axial and azimuthal locations to within $\pm 2 \times 10^{-5}$ in. (0.005% strain)
- Length measured to $\pm 10^{-3}$ in. to evaluate creep anisotropy.



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)



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	1873	1.03	Yes	--
		250	693 ⁽²⁾	5.83	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 shutdowns was done with sample pressurized.

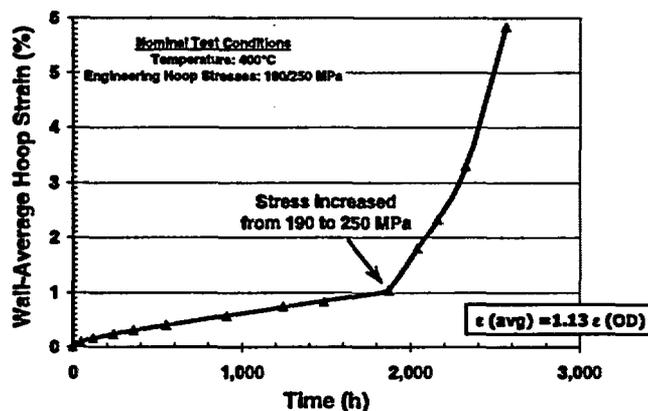
(2) Incremental hours

(3) On-going



Thermal Creep Tests – Surry C9

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



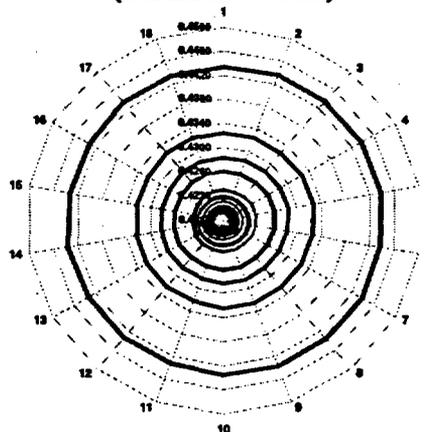
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Thermal Creep Tests – Surry C9

- 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)

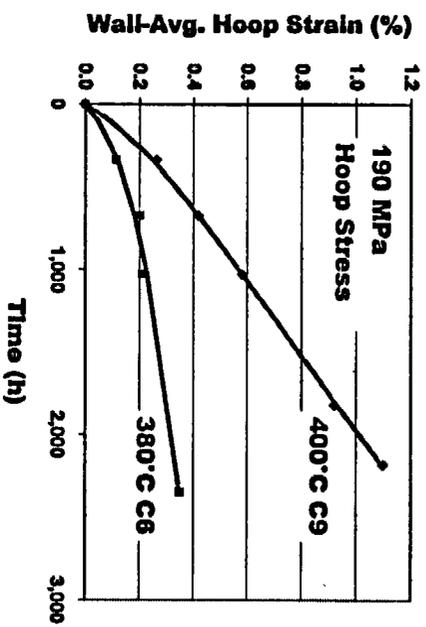


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Thermal Creep Tests - Surry

- Temperature Dependency

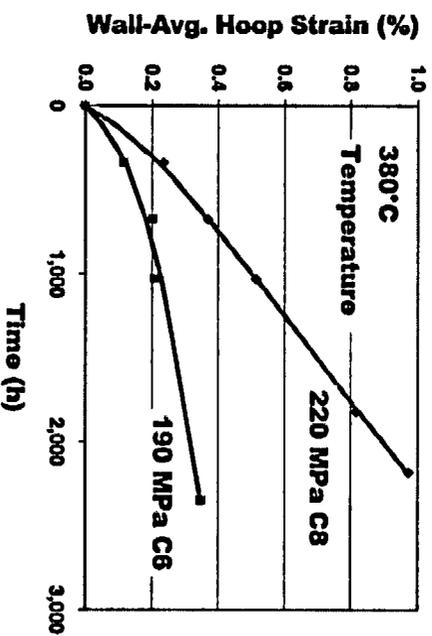


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Thermal Creep Tests - Surry

- Stress Dependency at 380°C

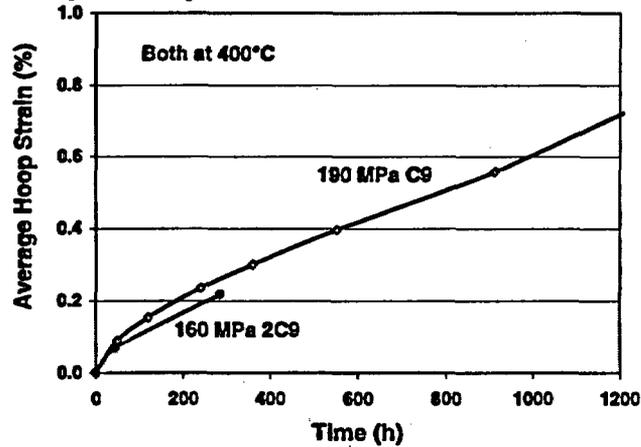


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Thermal Creep Tests - Surry

- 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% Gd₂O₃, 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

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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

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Thermal Creep Tests – H. B. Robinson

Robinson Test Matrix

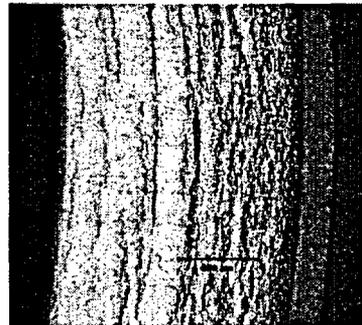
		(6/03) Stress (MPa)				
		100	160	190	220	250
Temp (°C)	420		1			
	400		1	C14 C15	1	
	380		1	C16	C17	
	360			1	1	
	320					

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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?

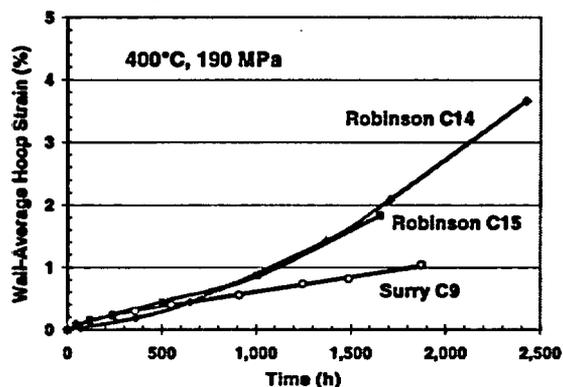


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Thermal Creep Tests – H. B. Robinson

- 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.



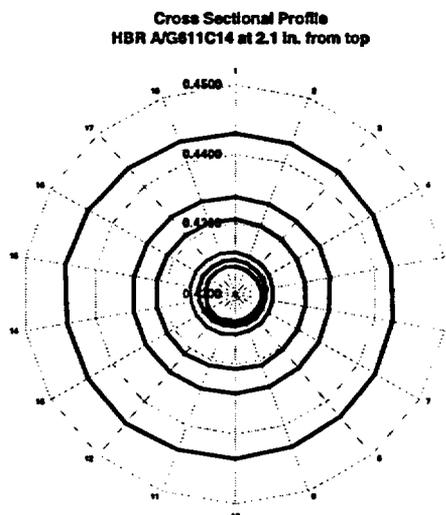
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Thermal Creep Tests – H. B. Robinson

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

- Max. local strain $\approx 5.3\%$
- Deformation still azimuthally uniform at end of test
- Additional creep life likely

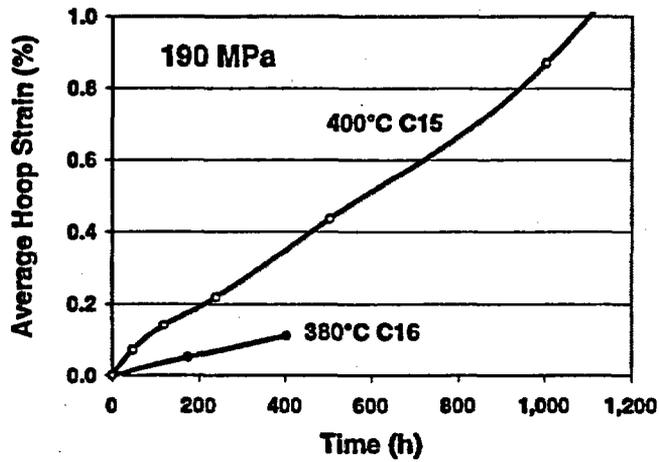


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Thermal Creep Tests – H. B. Robinson

- Temperature Dependency

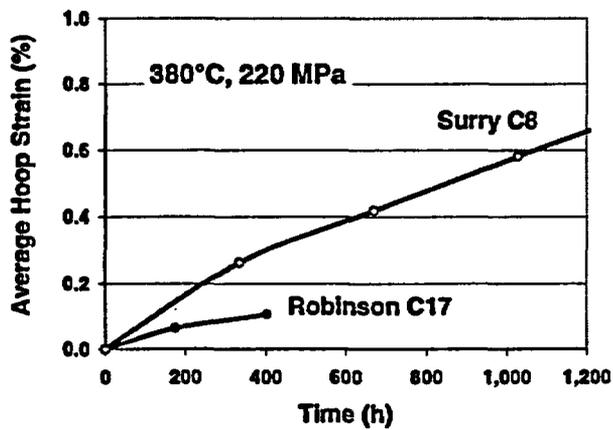


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Thermal Creep Tests – H. B. Robinson

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



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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 accommodate 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
-