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123RD MEETING OF THE ADVISORY COMMITTEE ON NUCLEAR WASTE

NOVEMBER 29, 2000

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TR08

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

MR. GARRICK: The meeting will come to order. This is the third day of the 123rd meeting of the Advisory Committee on Nuclear Waste. The entire meeting will be open to the public.

Today the Committee will tour the Center's experimental facilities, discuss the investigation and importance of ongoing Center-coupled processes related to repository design, and discuss miscellaneous matters related to reports.

Richard Major is the designated federal official for the initial portion of today's meeting. The meeting is being conducted in accordance with the provisions of the Federal Advisory Committee Act.

The Committee has received no written statements or requests to make oral statements from members of the public regarding today's session.

Should anyone wish to address the Committee, please make your wishes known to one of the committee staff. And it is requested that each speaker use one of the microphones, identify themselves and speak clearly.

Okay. We're now going to just deal with the agenda item that's labeled, "Investigation and Importance of Coupled Processes Related to Repository Design," and

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1 the Committee member that has the lead in this area is Ray  
2 Wymer.

3 MR. WYMER: I was pleased to hear yesterday  
4 from the DOE representative that they now consider that  
5 coupled processes are important and in fact may be one of  
6 the most difficult issues that they have to address. As  
7 many of you know, the Committee has been saying that for a  
8 long time.

9 So this morning we're going to hear and discuss  
10 reports of coupled processes related to alloy waste  
11 repository performance.

12 I presume we'll have still the full hour and a  
13 half, having lost 15 minutes this morning of the talk, I  
14 think we can still take the full hour and a half for this  
15 presentation.

16 So if our first presenter will come forward and  
17 introduce themselves, we'll get on with it.

18 MR. PABALAN: Good morning, ladies and  
19 gentlemen. My name is Bobby Pabalan from the Center for  
20 Nuclear Waste Regulatory Analysis.

21 This morning my colleague Debra Hughson and I  
22 will talk about the NRC and Center studies related to  
23 coupled processes as it affects repository performance.

24 The second viewgraph shows my outline. After a  
25 brief introduction, I will provide a short summary, a

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1 history of the Center and NRC studies of coupled  
2 processes, as well as the objectives of these studies.

3 And then Debra will follow with a discussion of  
4 Center studies on effects of coupled processes and seepage  
5 and flow.

6 Then I will come back and talk to you about the  
7 Center studies related to the effects of coupled processes  
8 on near field chemical environment, and I will follow up  
9 with a summary.

10 There is a general consensus in the literature  
11 that we need appropriate couplings of thermal, hydrologic,  
12 mechanical and chemical processes in safety evaluations of  
13 geologic repositories for nuclear waste.

14 NRC staff and Center staff believe that we need  
15 to consider thermal loads when evaluating mechanical  
16 processes in groundwater flow, and we think that the DOE  
17 will need to have an acceptable methodology for  
18 systematically considering thermal loads and thermally-  
19 induced mechanical, hydrologic and chemical processes for  
20 the design and performance of a geologic repository.

21 I've listed in the third viewgraph -- fourth  
22 viewgraph the principal factors of the DOE repository  
23 safety case as outlined in their Revision 3 of the RSS and  
24 note that five of the first five, seepage into the drifts,  
25 performance of the drip shield and waste package,

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1 solubility of the radionuclides and retardation in the  
2 unsaturated zone, we believe will be affected strongly or  
3 can be affected strongly by coupled processes.

4 The area of coupled processes and studies  
5 related to these have been of interest to the NRC and  
6 Center staff even early on in the NRC program at the  
7 Center.

8 Almost ten years ago, we did a systematic  
9 literature review with respect to coupled THMC processes  
10 that could be pertinent to the proposed Yucca Mountain  
11 repository. This review was published sometime in 1992.

12 Our of this literature review, a number of  
13 recommendations were made. For example, it recommended  
14 the development of conceptual and mathematical models  
15 beyond those that were available at that time.

16 It also recommended performance of well-  
17 documented coupled-effect experiments, as well as  
18 validation of models through comparison of model  
19 predictions and experimental observations.

20 Specific recommendations also include looking  
21 at synergistic effects between chemical reactions and mass  
22 transport under thermal conditions, as well as looking at  
23 mechanical stability of underground excavations under  
24 varying thermal and hydrologic conditions.

25 This set of recommendations was used as some of

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1 the basis for future work that the NRC and the Center have  
2 conducted in succeeding years and which we still do up to  
3 this point.

4 We did a number of studies looking at  
5 thermohydrology, thermochemical processes and  
6 thermomechanical studies. One of the early research  
7 projects that we had at the Center funded by the Office of  
8 Research at NRC was on thermohydrology. I believe this  
9 project was initiated way back in 1989.

10 Specifically, we looked at through laboratory  
11 experimentation and computer simulations the thermally  
12 driven moisture redistribution in partially saturated  
13 porous and partially saturated fractured media.

14 We also looked at the possible geochemical  
15 conditions in a heated geologic repository in one of our  
16 research projects also in geochemistry.

17 One of the more recent studies done here at the  
18 Center was to look at the drift stability and ground  
19 support performance under thermal and dynamic load in  
20 fractured rock mass. This was just published this year.

21 From my perspective, this study in  
22 thermomechanical drift stability is very interesting, not  
23 only the machination, but the conclusion of the study is a  
24 good example.

25 The results are in contrast or contrary to one

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1 would expect based on experience in conventional mining  
2 and tunneling.

3 The bottom line is the results indicate that  
4 thermally-induced rock mass deformation of highly  
5 fractured rock masses will be greater than the deformation  
6 of lower quality rock mass, which is in contrast to what  
7 one would expect based on conventional mining and  
8 tunneling experience. Lower quality rock mass would  
9 undergo greater deformation, and the results here are in  
10 contrast to that.

11 The previous studies that we have conducted  
12 focused mainly on either two-way coupling, for example,  
13 the thermohydrology studies, or in one-way coupling with  
14 respect to thermochemical and thermomechanical.

15 The last two bullets, we looked at the effects  
16 of temperature on the chemistry. We looked at the effect  
17 of temperature on mechanical stability.

18 It wasn't until we started the development of a  
19 fully-coupled THC computer code, which we call MULTIFLO,  
20 that we were able to simulate fully-coupled THC processes  
21 in one, two, three dimensional, 3-D special dimensions.

22 MULTIFLO allows us to model liquid and gas  
23 flow, heat transport, chemical transport, equilibrium  
24 speciation, as well as kinetically controlled mineral  
25 precipitation and dissolution.

1           Since the development of this MULTIFLO code, it  
2           has been a major tool for several of the NRC/Center KTI  
3           activities. We have used MULTIFLO to look at near drift  
4           THC effects on flow.

5           We have looked at ambient and thermally  
6           perturbed geochemical environments, seepage into drifts,  
7           as well as mountain-scale unsaturated flow under ambient  
8           and perturbed conditions. We've also looked at 3-D  
9           groundwater flow in natural thermal gradients.

10          In addition to those process level types of  
11          calculations, we have abstracted the results of those  
12          studies into our TPA code in most cases in the form of  
13          look at tables, for example, for concentration and the  
14          near field environment that could affect waste package  
15          performance.

16          The Center and NRC has also determined, based  
17          on previous studies, that incorporation of fully coupled  
18          thermal-hydrologic-mechanical-chemical processes, which  
19          means fully coupling of THMC, was determined not to be  
20          necessary for assessment of repository performance.

21          In other words, we can look at the couplings of  
22          these four processes two-way or maybe three-way, but we  
23          don't need to look at four-way couplings for those  
24          processes.

25          Now, the Center and NRC studies on coupled

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1 processes is being done in a risk-informed performance-  
2 based manner.

3 It means that we're not looking at all possible  
4 coupled processes. We cannot because of resource  
5 constraints. We have to focus on those that we believe  
6 will be important to repository performance.

7 The objectives of these studies are to test the  
8 validity of the assumptions and to probe the technical  
9 uncertainties of the DOE models and abstractions.

10 These studies also allow us to quantitatively  
11 assess the adequacy of the DOE safety case and the  
12 reliability of the DOE estimates of repository  
13 performance.

14 At this point I'll turn over the podium to  
15 Debra Hughson, who is going to talk about the coupled  
16 processes in seepage and flow.

17 MS. HUGHSON: Good morning. I'm Debra Hughson.  
18 I work here at the CNWRA, and as usual, these things  
19 advance too quickly.

20 I have three things I really want to talk about  
21 this morning. The first one on the bottom here is the  
22 laboratory work that I did to investigate a small scale  
23 process to see if water can actually get through the above  
24 boiling zone and arrive at the drift wall during the  
25 thermal period.

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1           And then depending on the time constraints, I'd  
2 also like to mention some work that was done by some  
3 colleagues of mine regarding the effects of  
4 thermomechanical effects. The issue there is that the DOE  
5 would like to ignore thermomechanical effects.

6           And then I'd like to also, if I could, talk a  
7 little bit about some work that Scott Painter has done  
8 with regard to the coupling of a thermohydrological  
9 chemical.

10           And the concern there is that our models really  
11 are showing something a little bit different than what the  
12 DOE's models are showing, and we'd like to look into that  
13 a little more.

14           This is some lab work that I did. The issue  
15 here is can water in the reflux zone focus by  
16 heterogeneity or gravity fingering into rivulets and  
17 actually flow through the above boiling zone and arrive at  
18 the drift wall.

19           And so what I did is I put together a Hele-Shaw  
20 model, which essentially you're looking at two plates of  
21 roughened glass that are pressed together and then we put  
22 heater strips on the back side here, these little brown  
23 things, so that we could increase the temperature going  
24 from the top down to the bottom.

25           And then we put in a flow rate. Right here at

1 the top we put in flow rates from .01 up to .4 millimeters  
2 per minute.

3 Now, the little thermocouples here on the  
4 front, these little white dots, you can see we're looking  
5 at what the temperature is on this Hele-Shaw model.

6 Now, right at this point here, you can see this  
7 is where the temperature was 100 degrees boiling before we  
8 started injecting the water.

9 Then as we injected the water here, we wound up  
10 getting the condensation up here in the cooler region, a  
11 two-phase zone here where gas vapor is rising and gravity  
12 drainage fingering down into the above boiling region.

13 Then where the infiltration was focused in, we  
14 wound up getting infiltration clear down to the point  
15 where the temperature was about 140, 145 C.

16 We have a model of this in our TPA code, given  
17 some work done by O.M. Phillips, which shows that the  
18 length that this can flow into the above boiling zone is  
19 the square root of the density of the water, the flow  
20 rate, phase change, thermal conductivity of the medium and  
21 the temperature gradient of the increasing temperature.

22 It also has a geometric factor in here and if  
23 you go through Phillip's derivation, this geometric factor  
24 turns out to be  $2/\pi$ , which for fractured, the heat is  
25 flowing radially around the infiltrating finger.

1           Now, I made some assumptions about one-  
2 dimensional heat flow through this Hele-Shaw model and I  
3 also assumed that the water was flowing at a constant  
4 velocity down.

5           And I wound up getting two models. I wound up  
6 getting a numerical model and an analytical model and I  
7 was able to back out what this geometric factor was for  
8 the Hele-Shaw model. It turned out to be about 1.2.

9           So that's kind of interesting. It shows that  
10 even for a fractured rock or for this Hele-Shaw model, I  
11 got a geometric factor reasonably close to one.

12           And so I concluded that this was probably a  
13 reasonably good model for looking at this small scale  
14 process.

15           I tried to combine this then with our dual-  
16 continuum MULTIFLO simulations. What you're looking at  
17 here kind of fuzzily is the liquid velocity condensate  
18 draining and refluxing in the fracture continuum.

19           These are no-flow boundary conditions on the  
20 side here and so this essentially replicates this thing in  
21 infinity in either direction, which is a reasonably good  
22 assumption for the center hot part of the repository.

23           Right in here is where I put the heat source  
24 for the drift. This is the centerline, through the  
25 centerline of the pillars.

1           The 50 years here, I wound up getting a maximum  
2 flow rate above the drift of 150-about millimeters per  
3 year, and then you can see the condensate draining down in  
4 the pillars where the temperature is below boiling. And  
5 the dry-out zone, the distance to the boiling isotherm  
6 from the drift crown was 4.7 meters.

7           At 200 years, this dropped off to about 48  
8 millimeters per year and the dry-out zone had increased a  
9 little over ten meters. And at 500 years, we're back to  
10 about 20 millimeters. The boundary condition I put here  
11 on the top was 10 millimeters a year in filtration.

12           So we're back down to just about twice the  
13 ambient infiltration in the refluxing zone here, and the  
14 boiling zone was about 10 meters or so.

15           So you can look at this to get the parameters  
16 for this model and you can see that the flux spikes up to  
17 about 150 in the first few decades of closure and then  
18 decays back down to the ambient level.

19           The dry-out zone, again, spikes up to about 10  
20 meters and, again, this is the hotter portion of the  
21 repository. The edges are cooler.

22           So then it begins to re-wet and decays back  
23 down. This is 2000 years right here, and this is the  
24 length in that length scale formula, the distance from the  
25 crown to the boiling isotherm.

1           And also, this is the flow rate in there, the  
2 maximum flow and the area that it's focused over. So what  
3 I can do from this is I can back out the area that you  
4 have to focus this refluxing flow over in order to get  
5 enough flow in a single rivulet that it will flow all the  
6 way to the drift wall.

7           And this is meters squared here and this goes  
8 from zero up to a hundred meters squared. This is years  
9 from zero to 2000.

10           What this suggests is that if this process is  
11 going to occur at the repository, it's most likely to  
12 occur early after closure.

13           And then you see you have to focus the flow  
14 over quite a large area during most of this thermal period  
15 to actually get water to the drift wall.

16           Now, as Bret Leslie pointed out to me, I'm  
17 neglecting ventilation in this model, the dry-out due to  
18 ventilation. So you might get a little bit of extra  
19 protection here because you have some dry-out initially  
20 due to the ventilation.

21           Now I'd like to switch gears here and talk just  
22 very briefly about some work that was done by Goodluck  
23 Ofoegbu. Goodluck was looking at the thermomechanical  
24 effects.

25           This is a cross-section through the mountain.

1 These little dots here represent the drifts. Now, this is  
2 a weekly coupled model.

3 Goodluck first looked at what effect thermal  
4 would have on permeability and then looked at the flow  
5 that would happen with those changes in permeability.

6 The story here is that the thermal effect tends  
7 to cause tension on the rock formation in between the  
8 drifts and the pillar.

9 This tends to open up the fractures which are  
10 horizontal and then the bottom line here is that this  
11 horizontal fracture dilation appears to cause some  
12 elevated flux within and on the downstream side of the  
13 thermally-mechanically altered zone.

14 Now, this is a work in progress. You see the  
15 scale here is relatively coarse. So these drifts are  
16 really reflected by one cell, and so we don't have any  
17 information about this causing increases or decreases in  
18 flow into the drift.

19 But it does seem to have some effect and so  
20 we're looking into this assumption that you can just  
21 neglect thermomechanical effects.

22 And finally, I'd like to talk briefly about  
23 some work that Scott Painter is doing. This is a strongly  
24 coupled model in that the precipitation of mineral species  
25 silica changes the permeability and porosity and then

1 those changes in permeability and porosity then go right  
2 back to the flow code and they affect the velocity.

3 So this is strongly coupled within a single  
4 time step. The chemistry sees the change in permeability  
5 and so does the flow field.

6 This is the drift here. This is saturation in  
7 the fractures of zero to 20. Over here is the fracture  
8 intrinsic porosity, which goes from zero to one.

9 And you can see that at 200 years here we're  
10 getting some significant changes in the fracture porosity.  
11 Above the drift here, the fractures are really tending to  
12 plug up.

13 This is significantly different than what the  
14 Department of Energy's models show right now and we're  
15 looking into that.

16 The preliminary indications tend to indicate  
17 that it may be perhaps the way that we're representing the  
18 gas permeability. The DOE is using a modified Cory  
19 relationship for gas permeability.

20 We're using the Vanganuken relationship for  
21 liquid permeability and then summing the relative  
22 permeabilities to one.

23 The process that really seems to be going on  
24 here is that the temperature is increasing the pressure  
25 within the matrix, which keeps the liquid phase, which



1 increases the boiling point and keeps the water in the  
2 liquid phase in the matrix, but it's above boiling in the  
3 fractures and the pressure is lower.

4 So as water migrates from the matrix blocks to  
5 the fractures, it flashes into vapor and deposits a silica  
6 deposit behind.

7 And so we're looking into the difference  
8 between the DOE's models and our models to really see why  
9 we're getting a different result. But it does appear to  
10 be fairly sensitive to the way that we're representing  
11 permeabilities of the matrix.

12 And so if there's no questions, I'd like to  
13 turn it back over to Bobby to talk briefly about the  
14 chemistry.

15 MR. GARRICK: There might be some questions.  
16 Ray?

17 MR. WYMER: No. That's quite a load for those  
18 of us who aren't very skilled in this area. I think I  
19 understand your conclusions pretty well, but I don't have  
20 any questions about it.

21 MR. GARRICK: Would your results have been  
22 different had you gone to more dimensions in your models?

23 MS. HUGHSON: I believe that the temperatures  
24 change with the dimensionality, and you tend to get higher  
25 temperatures in two-dimensional models. So in fact, if I

1 looked at a three-dimensional model, I might be seeing  
2 some decrease in temperature.

3 In terms of the velocities, I think that is  
4 probably reasonably close because we're taking a two-  
5 dimensional slice here, and so we're really looking at the  
6 dimension between the drifts.

7 This was just replicated along the drift in  
8 either direction. So I don't think that we'd see a lot of  
9 change in the saturation and the velocities, although  
10 again the temperatures might be a little bit different.

11 MR. GARRICK: Have you baselined this for a  
12 ventilated repository or cold repository?

13 MS. HUGHSON: Baseline?

14 MR. GARRICK: Well, have you done a similar  
15 kind of analysis for where the repository did not have a  
16 head load like this?

17 MS. HUGHSON: Well, what I did in these  
18 simulations, the MULTIFLO simulations, is I reduced the  
19 heat load for 50 percent for 50 years to simulate the  
20 effects of ventilation.

21 Now, you see the DOE is reducing the heat load  
22 by 70 percent, and we're asking them to back that up with  
23 data, and not just a simplified model.

24 Now, what we are neglecting is the removal of  
25 moisture from the drift during the ventilation period. I

1 believe, and we haven't looked into this specifically,  
2 although we do have some models in progress to actually  
3 look at the coupling, but what I suspect is that if you  
4 remove water from the drift during the ventilation period,  
5 we'd actually remove a little bit more heat, and that also  
6 you're removing mass so you would tend to get a little bit  
7 of a dry-out zone around the drifts, which may change the  
8 results perhaps in a conservative direction.

9 MR. GARRICK: A final question. Is the  
10 chemical composition of the water a factor at all in your  
11 calculations?

12 MS. HUGHSON: Now, I'm going to say that I  
13 believe that it is but I would like a chemist to --  
14 perhaps if Lauren, would you like to speak to that?

15 MS. BROWNING: Yeah, sure. I wasn't involved  
16 in the particular studies that -- Lauren Browning, CNWRA.  
17 Debra and I did some work earlier on it, a different  
18 application using MULTIFLO in which we varied the  
19 composition of the infiltrating water.

20 We found that it did have a large impact on the  
21 types of secondary phases that were predicted, the types  
22 of -- the changes in water composition over time.

23 MR. WYMER: I do have one followup question.  
24 How far in time are these effects important? When do they  
25 stop being important?

1 MS. HUGHSON: Well, now, the work that Scott's  
2 done, what I showed you there was 200 years, but the  
3 silica cap then persists indefinitely.

4 MR. WYMER: The deposits are there forever.

5 MS. HUGHSON: Yes, the deposits persist  
6 indefinitely. The thermal-mechanical effects I do also  
7 believe are permanent because what you have is a shifting  
8 along the plane of the fracture and the asperities then  
9 would change the aperture, average aperture.

10 In terms of the thermal-hydrology, the peak  
11 temperatures occur about 200 to 300 years in my model, and  
12 I'm winding up getting a rewetting back to ambient  
13 conditions after about 2,000 years.

14 Again, this is the hottest part of the  
15 repository and the edges would be cooler.

16 MR. WYMER: That's important.

17 MS. HUGHSON: Yes, it is important.

18 MR. WYMER: Thank you very much.

19 MR. LEVENSON: One question. In the Hele-Shaw  
20 cell experiments, the water addition rate that you used,  
21 where does that fit in the range of precipitation?

22 MS. HUGHSON: Well, again, what we're looking  
23 at here is a volumetric flow rate, and what I'm looking at  
24 in the models with the infiltration is a linear flow rate,  
25 length per time.

1           And so the way that I related the two, the flow  
2 rate that I used with the flow rate in the Hele-Shaw  
3 model, is by the area that you would have to focus it  
4 over.

5           But basically, the point of the Hele-Shaw  
6 model, which I'd like to show you on our lab tour, is to  
7 look at whether or not Phillip's relationship is valid for  
8 this particular process, and then going back to the  
9 MULTIFLO simulations to see what kind of linear flow rate  
10 we would get and then the area that we'd have to focus  
11 that over to reach the drift.

12           MR. LEVENSON: But for such a small finite size  
13 area, isn't that somewhat sensitive to the flow rate?

14           MS. HUGHSON: Say that again?

15           MR. LEVENSON: The distribution that you get,  
16 your temperatures are fixed. It seemed to me that there  
17 might be a significant difference in the liquid  
18 distribution, depending on the rate at which you're adding  
19 water to the system.

20           MS. HUGHSON: In the Hele-Shaw model?

21           MR. LEVENSON: Yes.

22           MS. HUGHSON: Well, again, the --

23           MR. LEVENSON: At the extreme you can flood it  
24 or you have such a tiny trickle that there's nothing. So  
25 the question is, how does -- this is representative of

1 percolation coming from precipitation; right?

2 MS. HUGHSON: No. Again, the purpose of the  
3 Hele-Shaw model was to look at Phillip's relationship and  
4 see if that's --

5 MR. LEVENSON: Yeah, yeah. But if it is  
6 sensitive to flow, flow relationship to area --

7 MS. HUGHSON: But again, the relationship of  
8 the flow to the area is to go back to the dual-continuum  
9 model and see how we can look at the small scale processes  
10 with Phillip's link scale given the parameters within the  
11 MULTIFLO simulation.

12 MR. LEVENSON: What I'm trying to ask is, was  
13 the flow ratio here in the middle of expected conditions  
14 or is this a bounding experiment?

15 MS. HUGHSON: Well, again, really neither,  
16 because what we're looking at, we look at a range of flow  
17 rates from a very small trickle up to something which is  
18 quite large, .4 millimeters per --

19 MR. LEVENSON: All in the Hele-Shaw cell?

20 MS. HUGHSON: In the Hele-Shaw cell, so we're  
21 looking at a whole range.

22 MR. LEVENSON: Oh, okay, because you just gave  
23 one number.

24 MS. HUGHSON: Oh, I'm sorry.

25 MR. LEVENSON: I withdraw all the other

1 questions. The implication was you were at one flow rate.

2 MS. HUGHSON: Oh, I'm sorry. No. We looked at  
3 a range of flow rates and a range of temperature  
4 gradients.

5 MR. WYMER: Are there any other questions?

6 MR. CLARK: Just following up on what Milt  
7 asked. There is an estimate of deep percolation. For  
8 different climates there are estimates of how much water  
9 will reach the drifts. How does your experiment compare  
10 to that?

11 MS. HUGHSON: Well, again, looking at this  
12 MULTIFLO simulation, I believe that 10 millimeters per  
13 year is somewhere in the range of this expected during the  
14 thermal period, the first 2,000 years.

15 And then going back to the Hele-Shaw model, all  
16 we looked at there was a range from a very small trickle  
17 to up to quite a large flow rate, and the temperature  
18 gradient and then looked at that range and how that  
19 related to Phillip's link scale.

20 And then we were able to say, well, yeah,  
21 Phillip's link scale is probably a reasonably good model  
22 for this range of flow rates, and then we looked at the  
23 simulations to see the actual conditions at the mountain.

24 MR. EWING: This is very interesting but I'm  
25 out of my depth, so maybe this is a silly question. But

1 for coupled systems, I'm always interested to develop a  
2 qualitative sense of the source and magnitude of  
3 uncertainty.

4 And you offer a very nice example of two  
5 conceptual models and with those two models also different  
6 barometric values, if I understood correctly. The heat  
7 load is different in yours versus DOE.

8 So when you have this situation, is there any  
9 way, from your point of view to compare these two  
10 conceptual models and quantify the uncertainties and  
11 source of the uncertainty?

12 MS. HUGHSON: So are you talking about the  
13 dual-continuum simulations?

14 MR. EWING: Right.

15 MS. HUGHSON: Okay. This is a big issue and  
16 this is probably the main focus of the TEF, the KTI that  
17 I'm involved with, is dealing with uncertainty.

18 And I believe that there is quite a bit of  
19 uncertainty which is not accounted for coming from various  
20 sources.

21 This is due to the calibrated properties that  
22 we use in the models, the inverse method, measurement  
23 error, scale effects, spatial heterogeneities, and so  
24 there's quite a number of uncertainties, I think, that  
25 aren't necessarily captured in the whole overall approach.



1           Now, when you compare our model to their model,  
2 well, you probably won't see a lot of difference because  
3 we're using their calibrated properties and we're  
4 basically using their heat load and so we're getting  
5 something fairly similar to what they're getting.

6           But again, this doesn't account for all the  
7 uncertainties, nor does their model account for all the  
8 uncertainties.

9           MR. EWING: Would that be part of this work to  
10 write an essay or provide a list of sources of uncertainty  
11 for some discussion of how they fit in?

12           MS. HUGHSON: Actually, yes. I did that for  
13 our IRSR this year. In Section 5.3 you can see that I  
14 spent a lot of time discussing these various sources of  
15 uncertainty.

16           You see what we're doing with the chemists and  
17 with the rock mechanics is we're looking at other sources  
18 of heterogeneity, which add more uncertainty, and we're  
19 looking at that effect on the flow processes, which is  
20 something that we're saying, okay, you just can't ignore  
21 that. You have to account for the uncertainty or the  
22 variability that those processes might cause.

23           MR. CAMPBELL: One question, Debra. In terms  
24 of the DOE model that the design where the drifts are hot  
25 out to a certain area and then the pillars are cool in

1 between the drifts, I'm not sure that the Hele-Shaw model  
2 addresses that specific design.

3 MS. HUGHSON: No. The Hele-Shaw model is not  
4 looking at anything in that scale. The Hele-Shaw model is  
5 looking at a very small scale process, which is happening  
6 within the grid blocks of the larger scale.

7 The larger scale model is going to be a coarse  
8 medium continuum that's volume averaged. It will see  
9 things like gravity fingering and preferential flow.

10 So the point of looking at the Hele-Shaw model  
11 was to visualize and look at the small scale processes and  
12 then go back to the volume averaged simulation and see  
13 what effect that might have.

14 MR. CAMPBELL: Okay. And have you done that or  
15 is that anticipated?

16 MS. HUGHSON: Well, actually, that was -- then  
17 when I went back and I looked at the volume averaged  
18 model, then I would say, okay, how does this small scale  
19 process, how is that going to affect what you see in the  
20 volume averaged larger scale model.

21 And from that I came to the conclusion that if  
22 you were to see this happen in the mountain or in a  
23 thermal test, for example, it should happen very early on.

24 Then as the dry-out zone got bigger and the  
25 refluxing zone magnitude got smaller, then you would have

1 to focus flow over a much larger area to actually see it  
2 reach the opening.

3 MR. CAMPBELL: Is there any evidence of this  
4 occurring in the heat drift test?

5 MS. HUGHSON: Well, that has to be a qualified  
6 no. We have not seen any evidence of it in the drift  
7 scale heater test, but then again you have to take into  
8 account that the drift scale heater test is essentially a  
9 ventilated test because the air can pass through the  
10 thermal bulkhead.

11 And so there probably -- if it were to happen  
12 there, it might not be seen because of this ventilation  
13 effect.

14 MR. CAMPBELL: Thank you.

15 MR. HORNBERGER: But isn't there an ongoing  
16 test with the sealed alcove?

17 MS. HUGHSON: The sealed alcove, yes, but  
18 that's looking more at the ambient conditions. What we're  
19 saying in terms of the cross-drift, and I'm glad you  
20 brought that up, is that there's a planned test for the  
21 cross-drift, the cross-drift thermal test.

22 And so in our IRSR, we came back and we said,  
23 okay, you might have blown it on the first scale test with  
24 this ventilation stuff. So think about this when you're  
25 designing the cross-drift thermal test and don't let it

1     happen again.

2                 MR. GARRICK: Good discussion.

3                 MR. PABALAN: The Center and the NRC have also  
4     been doing studies related to the chemistry and water in  
5     the near field environment.

6                 This is a key to understanding performance of  
7     the engineered barriers. We've done a number of studies  
8     to look at the temperature of water that enters into the  
9     drift, as well as the water on the surfaces of the drip  
10    shield and waste packages, and also look at the chemistry  
11    of water inside the waste packages.

12                The last two bullets pertain to studies that we  
13    have conducted based on the VA design and also the  
14    information provided in the TSPAVA.

15                These studies range from fully coupled THC  
16    processes to very quick calculations maybe on Excel  
17    spreadsheet.

18                This slide presents the work that we have done  
19    and continue to do. Actually, Lauren Browning did most of  
20    these calculations to look at the chemistry of water  
21    entering the drift. This is an ongoing study. It is  
22    incomplete.

23                For me, it is hard to overstate the difficulty  
24    in developing a coupled THC model. I've listed some of  
25    the parameters that go into these kind of simulations.

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1           We have to put in the water composition, the  
2 water flux, the porosity, permeability, thermal  
3 conductivity, et cetera, as well as thermodynamic and  
4 kinetic data for the minerals that you are considering in  
5 your assessment.

6           The approach that we have used is to calibrate  
7 the THC model for the ambient conditions based on  
8 available Yucca Mountain site data on groundwater  
9 chemistry, mineralogy and hydrologic properties.

10          This allows us to have confidence in the  
11 baseline conditions. I just showed some examples of a  
12 comparison between the calculated calcium concentration as  
13 a function of depth.

14          The yellow ones are the Yucca Mountain site  
15 data. The red ones are the calculated values. On the  
16 right figure will be the pH as a function of depth, again  
17 comparing the Yucca Mountain site data with calculated  
18 values.

19          So I think in order for us to have confidence  
20 in predicting the evolution of the chemistry when you put  
21 in heat, when you put in interactions with an engineered  
22 barrier system, I think one has to have confidence in  
23 these baseline conditions. You have to be able to  
24 represent what's there right now.

25          The NRC and Center approach is in contrast with

1     what the DOE has done. The DOE has decided to calibrate  
2     their simplified model. The model includes two minerals,  
3     calcite and quartz, to represent Yucca Mountain. They  
4     calibrated the model to a thermal perturbation event.  
5     That is, data from the heater test.

6             My understanding is, based on discussions with  
7     Lauren and with Debra, that this kind of modeling is not  
8     able to calculate the ambient chemistry at Yucca Mountain.  
9     So one has difficulty in having confidence in the  
10    predictive capability of this kind of approach.

11            Like I said, this NRC and Center work is still  
12    ongoing. What we intend to do is take the calculations  
13    further from ambient conditions and then to apply heat to  
14    see the evolution of water and to apply interactions with  
15    the engineered barrier system to see what other kinds of  
16    chemical changes occur as you do the fully coupled  
17    simulations.

18            We've done a little bit of analysis for the  
19    chemistry of water on the surface of the drip shield and  
20    the waste package.

21            We have been doing and will continue to do  
22    corrosion tests, and what we wanted to do is determine if  
23    they have used some solutions that are bounding or  
24    solutions that would be relevant to the Yucca Mountain  
25    environment.

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1           Our simplified analyses indicate, for example,  
2           that evaporation of J-13 type solutions can concentrate  
3           the water to 22,000 times its initial concentration.

4           Based on the initial flow and concentration of  
5           J-13 well water, we calculated that one can have up to  
6           0.14 mol/L of fluoride ion in the solution if it's  
7           evaporated.

8           Now, this concentration, according to our  
9           materials group, is within the window of susceptibility  
10          for titanium. So I think one needs to consider these  
11          kinds of processes when evaluating performance of the drip  
12          shield.

13          In contrast, although DOE said they will be  
14          conducting experiments with 20,000 times more concentrated  
15          solutions than J-13 well water, there is no fluoride  
16          present in their solutions.

17          Another point that was brought out yesterday is  
18          the potential effect of trace metals like lead on the  
19          performance of Alloy 22.

20                 MR. LEVENSON: Excuse me a second. On the  
21          previous one where you calculate a fluoride concentration  
22          of .14 mol/L, that's a calculated number. Does that  
23          assume that in a boiling down vapor reduction of 22,000,  
24          you don't volatilize any fluoride at all?

25                 MR. PABALAN: Yes.

1 MR. LEVENSON: That's what it sort of looks  
2 like.

3 MR. PABALAN: Yes.

4 MR. LEVENSON: Is that a valid assumption?

5 MR. PABALAN: Under the pH conditions, probably  
6 it is. The pH in these solutions would -- I don't have  
7 the pH here, but it would probably be around 10 or so. HF  
8 would be important under acidic conditions.

9 I don't know about the volatility of sodium  
10 fluoride.

11 MR. LEVENSON: At 22,000 times boil down, there  
12 are very few things that aren't volatile.

13 MR. PABALAN: The 22,000 times concentration  
14 occurs at a temperature of 120 degrees.

15 MR. CAMPBELL: Bobby, is this the -- have you  
16 done speciation --

17 MR. PABALAN: Yes.

18 MR. CAMPBELL: -- to establish that this is F-  
19 minus?

20 MR. PABALAN: I believe so. Lietai Yang is the  
21 one who did the calculations, but I would assume that it  
22 does.

23 We have used the -- it's 9236. It's the  
24 environmental simulation program systems, which can go to  
25 very high concentrated solutions, considering also



1 speciation.

2 MR. WYMER: Did you take into account the  
3 presence of calcium?

4 MR. PABALAN: Yes. Whatever calcium was  
5 initially in the J-13 well water, we put in those  
6 compositions and concentrations.

7 MR. WYMER: And allowed for precipitation?

8 MR. PABALAN: Yes. And as you evaporate, of  
9 course, the boiling point goes up, so we have to take it  
10 up to 120 degrees to bring it up to 22,000 concentration.

11 MR. CAMPBELL: Is this Upwell or Pitzer or  
12 what?

13 MR. PABALAN: It's a mixed Meisner, Romney  
14 approach.

15 [Multiple voices speaking at once.]

16 MR. PABALAN: With respect to the potential  
17 effects of lead on the stress corrosion cracking of Alloy  
18 22, we've done some preliminary calculations, allowing J-  
19 13 well water to evaporate assuming 3.1 ppm of lead  
20 initially based on the maximum concentration in solution  
21 that we found from the Yucca Mountain site.

22 The pH evolved from about 8 at 25 degrees to  
23 about 10 1/2 at 100 degrees centigrade, but what is  
24 important in this calculation is that most of the lead at  
25 that temperature after evaporation is really in the form

1 of lead carbonate species, and there's very low free lead  
2 ion available.

3 So there's a question of what's the mechanism  
4 for enhanced degradation of Alloy-22. If it's lead 2-plus  
5 that is causing the enhancement, then perhaps we don't  
6 need to be concerned about lead in the Yucca Mountain  
7 environment.

8 We've done some analysis of potential  
9 radiolysis effects on the chemistry of water in the drip  
10 shield and waste package.

11 The DOE analysis, the test that they're doing,  
12 assumed that the pH solutions would be greater than 2.7 of  
13 water in contact with a drip shield and waste package.

14 There is a potential for radiolysis to cause  
15 acidic condition. We've done some calculations showing  
16 that a couple of hundred years or even after 10,000 years,  
17 one can get very low pH's, even less than zero.

18 So we should note that there are a lot of  
19 assumptions in these kinds of calculations, the water at  
20 the surface, the closed system assumption for the  
21 calculations. But the potential effect of radiolysis has  
22 not been considered by the DOE in their analysis.

23 The same thing with the chemistry of water and  
24 contact with... The DOE assumes in their abstraction of  
25 the waste form degradation that the pH will be between 2.6

1 and 10.

2           There's a potential for radiolysis in this  
3 particular case to cause enhanced dissolution of the waste  
4 form of acid conditions. These calculations are for a  
5 couple of hundred years after breach of the barrier. So  
6 water in contact with the waste form could potentially be  
7 acidic.

8           Now, we should note that these are preliminary  
9 analysis. There's a potential for the pH to be buffered  
10 by interactions with the other waste components and that  
11 is something that we need to analyze with further  
12 calculations.

13           With respect to --

14           MR. WYMER: Excuse me. If you get to these  
15 very acidic conditions, then the question comes up again  
16 of can you keep the fluoride in the water.

17           MR. PABALAN: Yes. That's something that we  
18 needed to consider. These are separate analyses that we  
19 conducted and we do need to consider all these  
20 interactions.

21           MR. WYMER: And those are planned?

22           MR. PABALAN: Yes.

23           MR. LEVENSON: I have a question back on Graph  
24 21 where you plotted the total dose after closure and the  
25 pH of the film. Was that total integrated dose what was

1 used to calculate the radiolysis?

2 MR. PABALAN: I believe the --

3 MR. LEVENSON: Is that why they're plotted  
4 together?

5 MR. PABALAN: I'm not sure.

6 MR. LEVENSON: If so, I don't understand it at  
7 all because any drop of water coming down there is not  
8 exposed to a thousand years worth of radiation.

9 MR. PABALAN: I think the only assumption that  
10 I know is the nitric acid that forms on the surface  
11 doesn't go away. So if there's water on the surface,  
12 formation of nitric acid accumulates and it doesn't, you  
13 know, it just stays there.

14 MR. HORNBERGER: The basic question is how do  
15 the red crosses, the total dose after closure, relate to  
16 the blue diamonds, the pH?

17 MR. PABALAN: I believe those red dots  
18 represented dose used to calculate the generation of  
19 nitric acid.

20 The Center and NRC have --

21 MR. LEVENSON: One second. This also has the  
22 assumption in it that as this intermittently boils to  
23 dryness, you don't lose any nitric acid?

24 MR. PABALAN: Yes.

25 MR. LEVENSON: That's not really a valid

1 assumption by a couple orders of magnitude.

2 MR. PABALAN: Yes. That probably is not a  
3 valid assumption under the repository conditions.

4 MR. WYMER: It's just another reflection of the  
5 complexity of the interaction of the coupled reactions  
6 that are taking place here.

7 MR. PABALAN: Yes.

8 MR. WYMER: They really need to be accounted  
9 for and it's very complex to incorporate it.

10 MR. PABALAN: Okay. With respect to, again,  
11 the chemistry of water inside the waste package, a  
12 potential concern is the effect of corrosion products on  
13 the degradation of the glass.

14 All of our experiments indicate that when you  
15 have ferrous chloride or ferric chloride in the system,  
16 you have enhanced dissolution of the waste, of the high  
17 level waste glass relative to dissolution in the ionized  
18 water.

19 Granted that there is a similar effect when you  
20 have only HCl present, suggesting that the pH is a main  
21 factor, but still there is a difference that cannot be  
22 accounted solely by the presence of HCl, but which we  
23 believe is due to the presence of ferric cations.

24 MR. WYMER: You probably know that iron is used  
25 as a means of measuring radiation dose. Have you taken

1 into account the changes in the ferrous/ferric ratio with  
2 time as with radiation?

3 MR. PABALAN: No, we haven't. That is  
4 something that --

5 MR. GARRICK: Is that an important thing?

6 MR. WYMER: It could be if you get into  
7 discussions of reducing properties of ferrous ion with  
8 respect to technetium.

9 MR. GARRICK: Oh, yeah. Yeah.

10 MR. EWING: Can I just ask a question  
11 reflecting on your first statement here, "DOE  
12 abstraction..." et cetera "...ignores potential  
13 interactions with corrosion products."

14 By definition, an abstraction ignores a lot.  
15 It's supposed to capture the main features. So do you  
16 think that the things that follow that you list are really  
17 major features in capturing glass corrosion? I mean, we  
18 know every abstraction will suffer from this criticism.

19 MR. PABALAN: \*Stradar, I think, wants to take  
20 that question.

21 MR.\* STRADAR: Nararsi Stradar\* from the  
22 Center. First of all, these are some preliminary  
23 experimental results.

24 The purpose was really -- originally in our TPA  
25 model, we had ignored glass as a thermal heater dose

1 because the inventory was small and we felt the  
2 dissolution rate was also small enough that we could  
3 ignore glass and focus on spent fuel.

4 The purpose of these studies was to really test  
5 that hypothesis. If a corrosion product, for example, say  
6 iron, is present due to the dissolution of components of  
7 the waste package and then radiolysis, then we felt that  
8 -- and if the glass dissolution rate is increased, then  
9 perhaps we should also consider glass dissolution models  
10 in our TPA code.

11 So right now, where we are is that while we are  
12 criticizing DOE for not including the corrosion products,  
13 we also have to do some sensitivity studies using our TPA  
14 code to see whether this increased dissolution rate of the  
15 glass contributes significantly to dose. If it doesn't,  
16 then it's never mind.

17 MR. EWING: But the TPA presently doesn't  
18 include the glass?

19 MR. \*STRADER: Right. It doesn't.

20 MR. PABALAN: There's also a concern about the  
21 assumption of a J-13 well water composition. In DOE's  
22 analysis of waste form degradation, they assume that J-13  
23 composition enters into the waste package and that is what  
24 interacts with the waste package components.

25 We have initiated some experiments to try and

1 look at the chemistry of water that drips into the waste  
2 package. This diagram is just a cartoon of the  
3 experimental apparatus that we're using where we simulate  
4 some sort of a crevice in the Alloy 22 or at this initial  
5 stage, the 316L stainless steel.

6 And we're going to look at the chemistry of  
7 water that drips into the system that could interact with  
8 waste package components at some point.

9 The main question that we have is what is what  
10 is the pH of water that drips into the waste package? Is  
11 it really just J-13?

12 We expect in a crevice corrosion to get acidic  
13 pH and that's what we're trying to look at with this kind  
14 of experiment.

15 MR. WYMER: In the previous viewgraph you had  
16 something called "internal components."

17 MR. PABALAN: Yes. The initial experiments --  
18 there are two halves to this experimental system.  
19 Initially, we're just going to let water flow through this  
20 crevice so we can measure the pH and measure the  
21 composition as the 316L degrades.

22 The second part of the experiment is we will  
23 let this fluid in a flow-through type of experiment  
24 interact with, for example, glass or some other waste form  
25 simulant or waste package -- waste component.



1 MR. WYMER: What specific things do you have in  
2 mind to stick in there first?

3 MR. PABALAN: I believe glass is what is  
4 planned initially.

5 MR. WYMER: Iron, sooner or later?

6 MR. PABALAN: Yeah.

7 MR. WYMER: Okay.

8 MR. PABALAN: The VA design includes an  
9 estimated 179 kilometers of emplacement drifts in the form  
10 of concrete inverts and linings.

11 We were concerned at that time about the  
12 potential interaction of the alkaline fluids resulting  
13 from interaction with cement.

14 We did some coupled -- we did some THC -- no,  
15 hydrological chemical simulations to look at the potential  
16 interaction of the alkaline plume with the tuff host rock.

17 Our results indicate that you do get porosity  
18 reduction of the tuff matrix along the boundary between  
19 the concrete and the tuff that could isolate the matrix  
20 from fracture pore water, which could have an effect on  
21 transport and diffusion processes.

22 This kind of simulation did not consider the  
23 temperature effect, however. We couldn't do a THC type of  
24 simulation because we did not have the temperature  
25 dependence information.

1           So what we did as a next step is to do a number  
2 of experiments, actually done at the University of  
3 Aberdeen, to look at the temperature effects on the cement  
4 chemistry and cement properties.

5           Experiments were done by steam curing of  
6 Portland cement paste at 130 and 200 degrees Centigrade to  
7 look at the evolution of the minerals, of the cement  
8 minerals, initially CSH, calcium silicate hydrate gels as  
9 a function of time.

10           The figure is little bit busy but the bottom  
11 line coming out of this kind of study is that  
12 recrystallization of the initially amorphous CSH phases  
13 results in lower pH.

14           So when you have Portland present, the main  
15 component present in cement, you're going to have very  
16 alkaline pH of 12.4 or something like that, but as you  
17 recrystallize the amorphous CSH, then it goes down to  
18 lower pH's.

19           The thing that we take away from this is maybe  
20 in a heated repository one may not necessarily be  
21 concerned about the pH effects of the concrete lining.

22           MR. WYMER: Here you've got the pH going way up  
23 and another example of the radiolysis the pH is going way  
24 down. So there must be some sort of a null point there.

25           MR. PABALAN: Yeah.

1 MR. LEVENSON: That's why you couple them.

2 MR. PABALAN: The last study that we have  
3 initiated or we conducted actually relates to the TSPA-VA  
4 hypothesis that some of the radionuclides will be uptaken  
5 by secondary uranyl phases.

6 We wanted to be able to test the DOE hypothesis  
7 with respect to the importance of this process. We  
8 conducted some synthesis of uranophane, which we were  
9 planning to use in our experiments, but because the TSPA-  
10 SR will not take credit anymore for second mineral phase  
11 formation, we have relegated this --

12 MR. WYMER: What did you just say?

13 MR. PABALAN: I'm sorry?

14 MR. WYMER: You just said what? The TSPA will  
15 what?

16 MR. PABALAN: The site recommendation TSPA will  
17 not use the uptake of radionuclides by second phases.  
18 They will not take credit for it.

19 MR. GARRICK: No retardation.

20 MR. PABALAN: No retardation.

21 MR. GARRICK: From secondary products. It's  
22 amazing.

23 MR. PABALAN: They believe there's significant  
24 -- there's a lot of uncertainty with respect to the  
25 importance of that process, of that mechanism.

1           So they have decided not to take credit for  
2 retardation by secondary phases.

3           MR. WYMER: "They" is DOE?

4           MR. PABALAN: DOE, yes, which means this study  
5 is not as important anymore from the NRC perspective and  
6 this experiment right now is not being pursued by the NRC.

7           MR. HORNBERGER: Do you know if DOE is pursuing  
8 such experiments?

9           MR. PABALAN: I believe Argon National  
10 Laboratory is still doing some of those experiments.

11          MR. LEVENSON: Their not taking credit for it  
12 does not change the uncertainty. It just puts all of the  
13 uncertainty on the safe side.

14          MR. PABALAN: Yes.

15          MR. HORNBERGER: The problem that I see, and we  
16 had commented on this, the worry that I have is that a  
17 comment like that without having any data -- I mean, I  
18 would like to see some of these experiments done to either  
19 confirm or refute the fact that these secondary minerals  
20 might be a truly significant mechanism for immobilizing  
21 certain nuclides, neptunium in particular.

22                 And that's independent of whether it's in the  
23 performance assessment or not. I'd just like to know  
24 whether the process occurs.

25          MR. GARRICK: Have a major impact on the peak

1 dose.

2 MR. HORNBERGER: It could.

3 MR. GARRICK: Could have.

4 MR. HORNBERGER: On the other hand, if all we  
5 have are these statements that, oh, well, we're not taking  
6 credit for this so we're being terribly conservative, we  
7 don't really know how conservative.

8 MR. LEVENSON: I think there's a philosophical  
9 point, George, I agree with, and that is while NRC's job  
10 is primarily to review what DOE does, in order to decide  
11 whether the health and safety of the public is really  
12 being protected, we need to know where the conservatisms  
13 are, as well as what they're doing.

14 MR. GARRICK: Just pushing that a little  
15 further, has DOE presented any rationale for deciding not  
16 to --

17 MR. PABALAN: Yes. In the AMR and waste form  
18 degradation and PMR and waste form degradation, they do  
19 say, well, there's a lot of uncertainty with respect to  
20 how much radionuclide would be uptaken by secondary  
21 phases.

22 They cannot provide a high degree of confidence  
23 in the results to allow them to take credit for it.

24 MR. GARRICK: Well, as an old risk analyst,  
25 uncertainty, the existence of uncertainty is not a reason

1 for eliminating something. On the contrary, it's a risk  
2 for including something. But go ahead.

3 MR. McCARTIN: If I could, from the perspective  
4 of the program though, with a certain fixed budget with  
5 limited resources, we have to prioritize what we want to  
6 go after, and we are driven to a certain extent by where  
7 DOE is headed and weaknesses that we need to explore.

8 This is one of those cases while it can be an  
9 important process to reduce releases, looking on it just  
10 by ourselves doesn't make sense with other things out  
11 there like as you've heard discussed previously.  
12 Corrosion products, et cetera, are things more of  
13 interest.

14 MR. GARRICK: Right.

15 MR. LEVENSON: But Tim, our charter is  
16 different than yours. You have to live in the real world  
17 and can only do what your funds are.

18 If we see something we think is important and  
19 is not funded, it behooves us to point it out.

20 MR. McCARTIN: Agreed.

21 MR. EWING: Comment on these. I want to  
22 reinforce the statement that this could be very important.  
23 DOE may not take credit for it this year but next year it  
24 may be on the table, and these experiments are not easy.  
25 You can't turn them on and off. They take years to get

1 going handling radioactive materials.

2 The other point, work is being done around the  
3 country in other laboratories and there's no reason why we  
4 can't collaborate with people and take advantage of their  
5 funded programs to get at least some idea whether this is  
6 important or not.

7 And I'll bet you a lot it's potentially very  
8 important, particular for neptunium.

9 MR. McCARTIN: I won't disagree. However, I  
10 will say that if DOE is going to take credit for  
11 something, the burden of proof is on the Department of  
12 Energy. Our results are primarily confirmatory, research,  
13 tests, et cetera.

14 I do agree with you but ultimately DOE will  
15 have to defend.

16 MR. GARRICK: I think we got the message.

17 MR. PABALAN: So to summarize, it's clear that  
18 coupled processes could affect repository performance,  
19 especially in the near field environment.

20 Now, these effects, of course, are included  
21 indirectly and only indirectly in performance assessments,  
22 such that the NRC and the Center will need to continue to  
23 evaluate couplings of processes at a process level so that  
24 we can test the bounding assumptions, for example, of the  
25 DOE, or the ranges of parameters that they use in their

1 TSPA calculations.

2 The NRC and the Center, these evaluation of  
3 coupled processes is being done in a risk-informed  
4 performance-based manner. We need to continue doing these  
5 analysis and studies, but we have to focus on those that  
6 are important to performance.

7 Thank you.

8 Lietai, they have a question with respect to  
9 your calculations of radiolysis effects. Two things, the  
10 assumption of no evaporation occurs at the surface; is  
11 that correct?

12 Lietai Yang from the Center.

13 MR. YANG: Lietai Yang from the Center. I do  
14 not quite understand the question.

15 MR. PABALAN: The question with respect to  
16 this, I believe, and also to the next figure, the  
17 calculations are for nitric acid concentration and  
18 generation of acidic conditions.

19 There was an assumption of no evaporation of  
20 water and no loss of nitric acid due to the heat.

21 MR. YANG: The assumption is there is no loss  
22 of -- we assume that all the produced nitric acid will  
23 stay there, and we do not know any kind of mechanism that  
24 will react with the produced nitric acid so we just assume  
25 it keeps accumulating.



1           This assumption may be wrong but at the present  
2 time we have not seen any DOE calculations, so this is our  
3 preliminary approach.

4           MR. LEVENSON: Some of us that spent some years  
5 recovering nitric acid by steam distillation will tell you  
6 that it is very volatile, but I think there's a more basic  
7 point to be made.

8           The last bullet on your last slide, the use of  
9 pessimistic or bounding or extreme conditions is really  
10 not consistent with risk-informed performance-based  
11 manner.

12           You can't say you're doing it in a risk-  
13 informed performance-based manner when you take extreme  
14 assumptions.

15           You really, unless you're doing your best  
16 estimate and trying to identify the uncertainties that go  
17 with it, you're really not doing it risk-informed.

18           MR. PABALAN: I'm not going to argue with him.

19           The other question, I believe, is with respect  
20 to your figure, Lietai, on the dose that you use to  
21 calculate in the first figure for gamma radiolysis, did  
22 you assume -- those red dots, symbols, those are the dose  
23 rates that you used to calculate the nitric acid  
24 generation?

25           MR. YANG: This is for drip shield waste

1 package?

2 MR. PABALAN: Yes.

3 MR. YANG: Yeah, we derived at those because we  
4 have not seen the publication of dose for the EPA to  
5 define, so in '98, '97, DOE published a report calculating  
6 dose for...design. That calculation only was from zero  
7 years after emplacement to 150 years emplacement.

8 So we calculated that calculation. Of course,  
9 this is also preliminary because we have no other means to  
10 do the calculation.

11 MR. LEVENSON: Well, the question was slightly  
12 different. This is a continuous dripping in of water and  
13 the question was, it looks from the curve like a drop of  
14 water that dripped in in year 1000, you attributed for  
15 radiolysis purposes to all of the exposure or dose for the  
16 previous thousand years.

17 This looks like an integrated dose curve and  
18 yet the drops of water are exposed to the radiolysis dose  
19 of only the residence time, not the integral.

20 MR. YANG: Yeah. This nitric acid production  
21 predominantly in the air space. So that interaction  
22 of...and the nitrogen in the air. So we calculate the  
23 residence time. My understanding is to calculate the  
24 residence time of nitrogen in the air space, not the water  
25 dripping down.

1 MR. ESH: Dave Esh. That residence time would  
2 be even shorter because the air circulates pretty rapidly  
3 in the drifts, more so than the water.

4 MR. YANG: Okay. Our calculation is we assume  
5 that the closure is at 50 years. After the closure, we  
6 assume no circulation. Of course, this is also  
7 preliminary.

8 MR. MCCARTIN: I'd just like to offer one  
9 thought on the risk-informed part. We certainly agree for  
10 the risk-informed approach, but please appreciate that  
11 what you get is a snapshot of where we are today.

12 And all these calculations are very much  
13 iterative and we're starting down this path and sometimes  
14 the early calculations tend to make some more conservative  
15 assumptions that we refine as time goes on. But it really  
16 is a snapshot and it's not the final end point.

17 MR. LEVENSON: I think we appreciate that, Tim.  
18 The concern is sometimes, particularly on very limited  
19 programs, you don't have time to go back and very early  
20 assumptions get embedded, unfortunately.

21 MR. WYMER: Is that the end of the --

22 MR. PABALAN: Yes.

23 MR. WYMER: Any more comments? I want to make  
24 a few wrap-up comments.

25 MR. EWING: I have one comment going back to

1 the chemistry of the water inside the waste package. I'm  
2 surprised to learn that glass dissolution isn't part of  
3 that consideration because with commingled disposal of the  
4 fuel and the glass, one of the principal chemical  
5 components is glass. So it's hard to imagine how you  
6 would successfully model what happens inside the waste  
7 package without glass corrosion.

8 On top of that, if I understand correctly, your  
9 approach will be to see if that has any effect on the  
10 final dose and run through the calculation. But I'd  
11 simply point out that in terms of dose, the total activity  
12 in the glass is only 5 percent of the total activity in  
13 the repository.

14 So one difficulty is when you run that  
15 calculation, the corrosion of the spent fuel dominates  
16 that final dose calculation and it really doesn't give you  
17 a good idea of how important glass is to what's going on  
18 inside the waste package.

19 So this may be an example where that final  
20 calculation is not a useful discriminator of what you need  
21 to do to develop the models.

22 MR. PABALAN: Let me just make one  
23 clarification. The DOE does indeed consider the  
24 degradation of the glass in their calculations of the  
25 chemistry inside a waste package.

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1 I don't think we had that at the Center and at  
2 the NRC, we have not done that kind of calculation, but we  
3 do intend to do that.

4 With respect to the contribution of glass to  
5 the total dose and discriminating the effect of glass on  
6 total dose, I agree with you. It's hard to discern, just  
7 because the spent fuel has such a big inventory, what the  
8 contribution of glass would be.

9 MR. McCARTIN: Probably one aspect, I believe  
10 the technetium inventory in glass is fairly high. It's a  
11 non-trivial amount.

12 For the other radionuclides, yes, but it does  
13 have a substantial amount.

14 MR. LEVENSON: I think there's a more important  
15 issue related to glass and that is the present plans are  
16 to dispose of many, many tons of plutonium by the can-in-  
17 can process where plutonium wafers will be inside the  
18 glass. It's not at all clear that that's an insignificant  
19 contributor.

20 MR. EWING: If it becomes that 50 metric tons,  
21 to put it in perspective, the total inventory is around  
22 600, 650 metric tons.

23 MR. LEVENSON: Yeah, but this is concentrated  
24 by many, many orders of magnitude so that the number of  
25 canisters that need to fail is much, much less. It isn't

1 at all clear that it's not part of the risk.

2 MR. WYMER: With respect to technetium, once  
3 you breach the canister, the waste package and get into  
4 the fuel, it's not at all clear either that the technetium  
5 will be coming out as a... It's fairly certain that a  
6 significant fraction, maybe a third in some cases, of the  
7 technetium will be metallic and a finely dispersed  
8 technetium metal.

9 This is observed many times in the fuel  
10 reprocessing business, so that's another. So there are a  
11 number of things that are subtle, maybe second order, but  
12 they relate to important products. They really need to  
13 have some attention paid since those are the dose  
14 contributors.

15 I wanted to make a few comments. One, it's  
16 apparent, I think, that this whole business of coupled  
17 processes is extremely complex, almost impossible to model  
18 completely, first because the phenomena aren't even  
19 understood, and if they were, the data required to  
20 elucidate the phenomena are not available, either kinetic  
21 or thermodynamic.

22 And finally, the uncertainties in the mountain  
23 itself and the type and rates of water coming in are  
24 uncertain.

25 And another point is, and this gets into

1 something that was discussed earlier, you're always  
2 confronted with the problem, it seems, of what is needed  
3 now -- this gets at Tim's point -- to really evaluate the  
4 license application as we presently understand what will  
5 come in, and what might be needed in the future.

6 For example, if it turns out to the  
7 satisfaction either of the technical community or of the  
8 public, if you can't really guarantee that the C-22 will  
9 stand up, then what's your fallback, what's DOE's fallback  
10 position, what will they resort to.

11 One of the few areas they have yet to fall back  
12 on are the chemistry-related areas, things like secondary  
13 phase formation, incorporation of neptunium and others in  
14 the films.

15 So there's a balance. It's been pointed out  
16 that there's not enough time after you discover that  
17 things have changed to get the data, do the experiments,  
18 do the calculations to address the new approaches.

19 This either means that DOE has got to run out  
20 farther in the future with respect to when they put in  
21 their license application or that the NRC has to be able  
22 to evaluate it when DOE does short of shove it into the  
23 breach.

24 So there is a balance that's required. That's  
25 a nice matter of judgment to decide what might be these

1 important features that might be brought into the picture  
2 provided the picture changes.

3 I realize that's a tough question, but it's one  
4 that we really have to pay some attention to in trying to  
5 decide what are the key things that might be done if the  
6 C-22 can't be relied upon to the extent that it currently  
7 is being relied upon, either for technical or for  
8 political or public relations reasons.

9 I asked the question yesterday of the DOE  
10 representative, "Do you consider in your decision making  
11 and what you decide you can and can't do the public  
12 input?" And the answer was, " Yes." And I think that  
13 they must incorporate that into their thinking. So that's  
14 one thing I wanted to say.

15 Another is that the situation is so complex  
16 that in fact, you can't really do it. You can't solve the  
17 coupled chemistry problems analytically. There are just  
18 too many.

19 So it's extremely important, in my opinion  
20 anyway, to carefully design experiments that come as close  
21 as you can possibly make them to simulate what will happen  
22 in the repository.

23 That's one way to sort of get a look at what  
24 might happen in an overall chemical sense. You couple all  
25 the processes experimentally instead of analytically and

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1 you try to find out what the result is.

2 That's the reason I thought that your figure on  
3 page 24 was particularly important because that comes as  
4 close as anything I've seen described as trying to get an  
5 integrated coupled look at everything that might happen in  
6 a repository.

7 I would urge you to think as carefully as you  
8 can about designing experiments. Grasp all of the  
9 couplings in reasonable rational chunks as nearly as you  
10 can to deal with these things experimentally that you  
11 can't hope to deal with analytically.

12 And I guess that's probably my sermon today.  
13 Any other observations or comments? Rod, what do you want  
14 to say about this?

15 MR. EWING: Your sermon was much appreciated.

16 MR. WYMER: Okay. Very good. I think you're  
17 doing a good job here and I think you've got a lot of work  
18 yet to do.

19 MR. GARRICK: Before we break up, I want to do  
20 a couple of things just as closing. When we came in here  
21 two-and-a-half days ago, we came in with a strong desire  
22 to learn more about the high level waste program, the  
23 tools that are being employed, the guidance that's being  
24 provided and the capability.

25 And while it's been a very congested agenda

1 with tremendous amounts of material thrown at us, I think  
2 the Committee in general is very pleased with the job that  
3 was done in terms of responding to the ground rules for  
4 the meeting.

5 In that regard, we certainly want to thank all  
6 the speakers. This is a tough duty. The presentations  
7 were excellent and the frustration the Committee always  
8 has in this kind of engagement is having an adequate  
9 amount of time for exchange and discussion and we always  
10 work on that problem.

11 The 50 percent rule doesn't always work where  
12 we ask the presenters to allow us about half the time for  
13 discussion, but we're going to keep pressing for something  
14 like that. But the speakers did an outstanding job and we  
15 want to thank them.

16 We also want to thank the Center staff and  
17 management, as well as the NRC. This meeting was handled  
18 extremely well.

19 The cookies were excellent. The weather was  
20 good. The transportation was good, although my driver got  
21 lost a couple of times.

22 But we would like to especially thank Wes  
23 Patrick and Budhi Sagar\*. Also the people that handled  
24 the audio-video, Theron Brown in Washington, and Melissa  
25 Van Hecke\* here, because it's a very difficult thing to do

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1 and I think they did a commendable job.

2 And we would like to than everybody that was in  
3 attendance. The interest they showed, the discussions  
4 that they added, and the break corridor interactions that  
5 took place were all very constructive.

6 MR. WYMER: I think we nearly killed our  
7 recorder yesterday.

8 MR. GARRICK: Yes. So unless there's another  
9 comment to be made by anybody, if anybody has a question,  
10 I'm going to adjourn this part of the formal meeting and  
11 allow us to prepare for our tour.

12 Adjourned.

13 [Meeting adjourned.]

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CERTIFICATION OF TRANSCRIPT

I, Ellen Walters, hereby certify that this is the transcript of the proceedings held before the U.S. Nuclear Regulatory Commission in the matter of the 123RD MEETING OF THE ADVISORY COMMITTEE ON NUCLEAR WASTE, at SAN ANTONIO, TEXAS, on November 29, 2000, and that this is a full and correct transcript of the proceedings.

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My Commission Expires: 12/31/01

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