

**NUCLEAR REGULATORY COMMISSION**

**ORIGINAL**

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Audit Review of Chemistry Issues for the  
Yucca Mountain Site Recommendation  
Considerations Report

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UNITED STATES OF AMERICA  
NUCLEAR REGULATORY COMMITTEE  
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ACNW AUDIT REVIEW OF CHEMISTRY ISSUES  
FOR THE YUCCA MOUNTAIN SITE RECOMMENDATION  
CONSIDERATIONS REPORT

(ACNW)

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WEDNESDAY

FEBRUARY 21, 2001

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ROCKVILLE, MARYLAND

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The ACNW Audit Review Committee met at the  
Nuclear Regulatory Commission, Two White Flint North,  
Room T2B1, 11545 Rockville Pike, at 8:30 a.m., Dr.  
Raymond G. Wymer, Chairman, presiding.

COMMITTEE MEMBERS:

- DR. RAYMOND G. WYMER, Chairman
- DR. JAMES CLARKE, Member
- DR. PAUL SHEWMON, Member
- DR. MARTIN STEINDLER, Member

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ACRS STAFF PRESENT:

DR. ANDREW C. CAMPBELL

DR. TAE AHN

DR. JOHN BRADBURY

DR. RICHARD CODELL

DR. GUSTAVO CRAGNOLINO, CNWRA

DR. BILL DAM

DR. CARL DIBELLA, NWTRB

DR. BRET LESLIE

DR. TIM MCCARTIN

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

(8:30 a.m.)

CHAIRMAN WYMER: Let's start. I want to kick the meeting off by reading some prepared comments that I have, and that will be the last formal thing that we will do, I think, and we will get into the informal.

So I will go ahead and read this stuff and it will take about the amount of time that I have allotted for it. And part of it is background material that I think everybody knows, but it is sort of for the record.

The Yucca Mountain repository site characterization activities are specified in NC geological repository regulations. NRC repository licensing requirements are contained in the proposed Part 63 of the Code of Federal Register.

And the process that the NRC carries out is as follows. The NRC strategic planning assumptions call for early identification and resolution of issues related to potential licensing of the repository. Considerable pre-licensing work is carried out by DOE and NRC both separately and jointly, to identify, clarify, and resolve issues associated with site characterization and performance.

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1           To facilitate this process, NRC has  
2 identified what are called Key Technical Issues, and  
3 publishes Issue Resolution Status Reports on the Key  
4 Technical Issues based on an issue resolution process.

5           The process is carried out through -- and  
6 I call them formal pre-licensing consultations with  
7 DOE. These consultations are required by law and are  
8 carried out in open meetings.

9           During the consultations, DOE orally  
10 presents information on technical issues to NRC staff  
11 and contractor personnel. The information presented  
12 is supported by DOE technical documents, though not  
13 necessarily at the time of the presentations.

14           Questions on the presentations are  
15 permitted by the public, as well as by NRC  
16 representatives. At the conclusion of the  
17 presentations, NRC staff and contractor personnel  
18 caucus to discuss the DOE presentations.

19           The purpose of the caucus is to determine  
20 what, if any, additional information NRC believes is  
21 required from the DOE for NRC to provisionally close  
22 the issue.

23           The deliberations of the caucus are  
24 presented by NRC staff to DOE at the time of the  
25 meeting, and DOE responds at that time, either

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1 agreeing to provide additional information, or taking  
2 exception to NRC's requests. This exchange between  
3 NRC staff and DOE is iterative over time. That is,  
4 they do it many times on the same topic.

5 The DOE Yucca Mountain repository Yucca  
6 Mountain repository safety strategy relies on  
7 engineered and natural barriers, and natural  
8 attenuation -- for example, radioactive decay -- to  
9 contain and isolate the radioactive wastes from the  
10 public.

11 DOE has identified four waste system  
12 attributes as being most important for predicting  
13 engineered and natural barrier performance. The first  
14 is limited water contacting the waste package. The  
15 second is long waste package lifetime.

16 The third is slow rate of release of  
17 radionuclides from the waste forms, and the fourth is  
18 concentration of reduction of radionuclides during  
19 transport through engineered and natural barriers.

20 In this working group, we will address all  
21 four of these attributes to the extent that they are  
22 chemical in nature. The first attribute, limited  
23 water contacting the waste package, is related  
24 chemically to corrosion of the titanium trip shield  
25 which covers the waste packages.

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1           It is also related to climate, to the  
2 design of the repository and to fuel emplacement,  
3 which affect repository temperature and temperature  
4 profiles for hundreds of years, and to a certain  
5 extent the paths followed by water in the repository.

6           The second attribute, long waste package  
7 lifetime, is related chemically to corrosion of Alloy  
8 22, the outer waste container material. In DOE's  
9 present repository safety conceptualization, this is  
10 the single most important factor in determining  
11 repository safety.

12           This attribute is also related to  
13 container fabrication, to damage that could be caused  
14 by material falling from the walls of the drifts  
15 containing the waste packages, or to mishandling of  
16 the packages.

17           Drifts could be damaged by earthquakes or  
18 by volcanism, as well as by less extreme events, such  
19 as thermal cycles or water damage.

20           The third attribute, slow rate of release  
21 of radionuclides from the waste forms, is chemical in  
22 nature through the solubility of the waste forms in  
23 the water contacting them, to colloid formation, to  
24 secondary phase formation, to temperature, to redox  
25 reactions, and to the rate of water contact with the

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1 waste forms, which in turn are all related to  
2 corrosion of the drip shield, corrosion of the waste  
3 packages, and corrosion of the cladding, in the case  
4 of spent fuel.

5 The fourth attribute, concentration  
6 reduction of radionuclides during transport through  
7 engineered and natural barriers, is related to the  
8 chemical species of the radionuclides released from  
9 the waste form and to the chemical nature of the media  
10 through which they move.

11 In this working group, we will concern  
12 ourselves only with those media within the drifts;  
13 that is, with corrosion products, with organic  
14 material, if any, with the rock beneath the waste  
15 packages, with the inverts and with the waste  
16 packages' supports.

17 If in the future backfill is considered  
18 for the drifts, then these media will also be  
19 important in radionuclide transport.

20 The purpose of this meeting is to discuss  
21 selected chemical issues in the near-field, and to  
22 reach a consensus among members of the working group  
23 that will lead to a written evaluation of the NRC  
24 staff process and activities in formally resolving  
25 selected parts of the Key Technical Issues related to

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1 the chemistry in the repository near-field.

2 In addition, the adequacy of the  
3 abstractions of the models used to address the  
4 technical issues into the Total System Performance  
5 Analysis will be addressed, as will the extent to  
6 which the working group believes the NRC requirement  
7 of Defense-in-Depth will be met by DOE.

8 If deemed appropriate, the working group  
9 will also comment on the degree to which conservative  
10 assumptions challenge the credibility of the analyses  
11 of coupled, thermal, hydrological, and chemical  
12 phenomena in the near-field.

13 A final point to be addressed is how well  
14 NRC has been able to prepare itself for  
15 contingencies; that is, to prepare for the unexpected,  
16 or to changes or changes in emphasis in the DOE  
17 licensing strategy.

18 These goals will be reached in part by  
19 exploring the issues identified in the four attributes  
20 discussed above, by critically examining the  
21 information requested and obtained from the DOE, and  
22 developed by the NRC staff and the Center for Nuclear  
23 Waste Regulatory Analysis, and by providing written  
24 comments based on what we learn.

25 Now, those are sort of my formal comments.

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1 Let me add to that fact that what we are doing is what  
2 we in the Advisory Committee on Nuclear Waste call a  
3 vertical slice.

4 We are looking at specific key technical  
5 issues. There are too many technical issues for us as  
6 a committee to address all of them. So in order to  
7 assess the process that the staff goes through in  
8 evaluating DOE's proposal, we are taking four.

9 Each of the four members is taking a  
10 vertical slice of a key technical issue, and our key  
11 technical issue relates to chemistry in the near-  
12 field.

13 And by a vertical slice, we mean that we  
14 are looking broadly at how things are done in the  
15 process, and in detail, and in this particular case  
16 the chemistry that has been studied, and the chemical  
17 processes that are explored.

18 So we are looking at the chemistry issues  
19 in the near-field in depth so far as we can, and in  
20 this particular case, the chemistry issues with this  
21 group of consultants with staffer, Andy Campbell.

22 So that is what we mean by a vertical  
23 slice. So we will not look as a committee, as an ACNW  
24 committee at all of the KTIs, but only a selected few,  
25 and from these, we will try and gain some feeling for

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1 how well the process works, and we will comment on  
2 that.

3 The members here of this group are Dr.  
4 Paul Shewmon, Dr. Martin Steindler, and Dr. James  
5 Clarke; and Dr. Andrew Campbell is the staff member  
6 who is every bit as important and involved in this as  
7 -- and maybe or probably more so as the rest of us.  
8 So, with that --

9 DR. CAMPBELL: And more importantly, I am  
10 the designated Federal Official for this meeting,  
11 since we are conducting this as an open meeting. So  
12 now that that is over with --

13 CHAIRMAN WYMER: Let me say that we could  
14 have held this as a closed meeting since there is only  
15 one member of the ACNW present. We decided not to  
16 hold it as a closed meeting in keeping with the NRC's  
17 policy of openness, and permitting the public and  
18 interim people to come and see what we are doing, and  
19 hear how we do it, and how we go about it.

20 So we think we are in complete compliance  
21 with all of the Federal Advisory Committee -- what is  
22 it, FACA?

23 DR. CAMPBELL: Federal Advisory Committee  
24 Act, FACA.

25 CHAIRMAN WYMER: And I think we are in

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1 agreement with all of the FACA requirements. However,  
2 I want to retain the flavor of a small group of people  
3 discussing openly their opinions.

4 I hope that nobody in the committee here  
5 is reluctant to someplace along the line take an  
6 extreme position with the expectation that the other  
7 members of the group will beat him back to a more  
8 rational position, because I think that is probably  
9 the way you get at the issues best in this sort of an  
10 arena.

11 So what some of us might say -- although  
12 we are not going to be crazy, but what some of us  
13 might say will not necessarily be what appears in the  
14 final report, but is merely a device, a mechanism, to  
15 more fully explore the issues.

16 I will permit comments and questions from  
17 the audience. However, in the interest of getting on  
18 with it and the time being so limited with all the  
19 topics that we have to cover, I would ask that those  
20 be held until the end of the day.

21 We will allow time this afternoon for  
22 comments and questions. However, we would like to  
23 feel that we can draw on the expertise of those  
24 present in the room and at the center when questions  
25 come up that we don't have the answers, and we have

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1 not been able to dig out the answers to, and we think  
2 that somebody else might know the answer, because we  
3 have not been emersed in this for the last 7 or 8  
4 years like some of the people have, and we are not  
5 necessarily as familiar with the details as we would  
6 like to be.

7 So with that, let me ask Andy if he has  
8 any comments that he wants to make from the staff's  
9 point of view.

10 DR. CAMPBELL: Just some housekeeping  
11 items. In terms of the meeting, I have not received -  
12 - and I don't think Ray has received -- any requests  
13 by anybody to speak. But if somebody does desire to  
14 speak, contact me or let Ray know.

15 But let me know and then we will arrange  
16 for some sort of time for you to be able to speak.  
17 But what we prefer to do is to do that at the end of  
18 the day if anybody wants to make any points.

19 CHAIRMAN WYMER: Right.

20 DR. CAMPBELL: But certainly we will be  
21 willing to accommodate somebody's schedule, for  
22 example.

23 DR. CAMPBELL: Yes. If somebody has to  
24 leave early, and it is something that they really feel  
25 should be said, and that they feel strongly about, or

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1 that it is a factual matter that we have gotten wrong,  
2 and they want to put into the record, fine. We will  
3 certainly allow for that. We are not going to be  
4 rigid, but we are going to be firm.

5 DR. CAMPBELL: Okay. What I have done  
6 -- and I guess I am next on the agenda here -- is the  
7 intent -- of course, the one thing I am missing is a  
8 pen.

9 As I put together some view graphs that  
10 are basically -- and in fact they are just excerpts  
11 out of TSPA or some of the AMRs and PMRs that I  
12 thought illustrated some of the key issues that we are  
13 going to talk about, in terms of waste packages, and  
14 I am sure that Paul is going to have additional things  
15 to say or comments.

16 But this would be a way of getting  
17 started, and so I am going to hand these handouts out,  
18 but I am going to attempt to do this via Powerpoint,  
19 and we will see how successful or not it is if we do  
20 it that way.

21 So what I am going to do is that I am just  
22 going to go ahead and go over this. The main point of  
23 this slide is just to make sure that we all know what  
24 the layout of the proposed layout of the drifts are,  
25 in terms of the types of packages, and the kind of

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1 loading that they are doing.

2 The first package you see there is a PWR  
3 package that contains -- I think the PWRs contain 44  
4 bundles.

5 CHAIRMAN WYMER: Lots. No, that is the  
6 BWR.

7 DR. CAMPBELL: It is a lot. It is a lot.  
8 But there is a difference between the PWR and BWR  
9 bundles, and it is not 44. The next package are the  
10 co-disposal packages, which consist of stainless steel  
11 flasks that contain high level waste flasks, along  
12 with defense nuclear waste or spent fuel.

13 These packages are line loaded. I believe  
14 Naval reactor fuel also goes into the repository,  
15 where they put the shipping cask inside the Alloy 22  
16 stainless steel disposal cast.

17 And then the whole business is covered  
18 over with a titanium drip shield. They are going to  
19 line load these things so that they are end to end  
20 basically, with a very short distance between waste  
21 packages.

22 DR. STEINDLER: What are they resting on?

23 DR. CAMPBELL: They rest on a pallet like  
24 device which consists of Alloy 22, which is at the  
25 contact with the waste package, I believe, and

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1 stainless steel.

2 CHAIRMAN WYMER: Is it stainless or  
3 carbon?

4 DR. CAMPBELL: It may be carbon steel, but  
5 it is a steel cradle if you will.

6 CHAIRMAN WYMER: Yes, it's carbon.

7 DR. CAMPBELL: But my understanding is  
8 that there is going to be at the contacts an Alloy 22  
9 service.

10 DR. DIBELLA: It says stainless steel here  
11 in the picture.

12 DR. CAMPBELL: That's what I thought.

13 DR. DIBELLA: And underneath there is  
14 stainless steel beams.

15 CHAIRMAN WYMER: Well, let's go ahead.

16 DR. CRAGNOLINO: The stainless steel tube  
17 supports it underneath?

18 DR. CAMPBELL: Yes. Underneath that is  
19 the invert, which I will show a picture of in just a  
20 minute, but it is basically -- originally the liners  
21 of the drift -- the drift support was going to be a  
22 concrete liner, and that was in the VA design.

23 They redesigned the repository after the  
24 viability assessment, and basically what you are  
25 looking at are steel drift supports and rock bolts,

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1 and that sort of thing.

2 CHAIRMAN WYMER: And grouting.

3 DR. CAMPBELL: And the kinds of things  
4 that you see in there right now.

5 CHAIRMAN WYMER: The rock bolts is grouted  
6 in.

7 DR. CAMPBELL: And they are grouted in,  
8 right. The invert itself originally in the VA design  
9 was a concrete pad, and in this design it basically is  
10 a steel framework that is filled with crushed top rock  
11 from the Yucca Mountain environment.

12 And the design after VA originally  
13 envisioned putting backfill over the dip shields, but  
14 DOE backed off from that after doing some further  
15 calculations and deciding that the insulating effect  
16 of that backfill would cause the cladding temperatures  
17 to exceed 350 degrees centigrade, which they have set  
18 as an upper limit to preclude creek rupture of the  
19 cladding inside the containers, and inside the  
20 disposal containers.

21 This is a cross-sectional view of how they  
22 envision this will look through time. You have some  
23 rubble, and eventually of course the drift supports  
24 aren't going to prevent everything from caving in, and  
25 so there will be some rockfall around and on top of

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1 the drip shields.

2 The potential for water dripping in comes  
3 from -- well, the current models look or focus  
4 primarily on the crown drip as a focal point for  
5 dripping water.

6 Some of the processes that would occur is  
7 in the dripping water you may have colloids, and there  
8 may be chemical properties of this water that are  
9 different from the natural water, either the pour  
10 waters or the percolating water from the surface,  
11 because of interactions with the steel and the  
12 support, or in the rockbolts and the cement, and the  
13 grout and the rockbolts.

14 That is a possible source of chemistry  
15 changing. The gas content in the drip, they evaluate  
16 not only the water content, but also the oxygen, the  
17 CO2, and the nitrogen.

18 And the CO2 content, and the oxygen  
19 content, and the water content, are all related to one  
20 another as a function of temperature. The drip shield  
21 is titanium as I pointed out. The emplacement pallet  
22 as we discussed is Alloy 22 and stainless steel.

23 The invert here underneath the package is  
24 crushed tough. So it is local rock. And that's  
25 pretty much it.

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1 DR. STEINDLER: We expect water to be in  
2 liquid form, but not right away.

3 CHAIRMAN WYMER: That's right.

4 DR. CAMPBELL: That's right.

5 DR. STEINDLER: That looks like a picture  
6 that is what, 5,000 years old?

7 DR. CAMPBELL: Or much longer frankly, in  
8 terms of water dripping on the waste package itself.  
9 I have a slide that I pulled out earlier on that.

10 This just shows the details, some of the  
11 details of the design. A key point here is that DOE  
12 has focused on the welding. They have a double-welded  
13 lid, a double-lid closure, and the package itself is  
14 annealed prior to or during the manufacturing process.

15 So the goal of that is to relieve the  
16 residual stresses created when they put the whole  
17 thing together. But because they are welding the lid  
18 on, there will be stresses associated with these lid  
19 welds.

20 And they have added this double-lid  
21 because of an attempt to have a defense-in-depth type  
22 of approach.

23 DR. SHEWMON: Annealed in air, or in  
24 hydrogen?

25 DR. CAMPBELL: I don't know how they are

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1 going to anneal it, and maybe --

2 DR. SHEWMON: There are some advantages to  
3 letting it oxidize. I just wondered.

4 DR. CAMPBELL: They are talking about  
5 laser pining as one.

6 DR. SHEWMON: That is for the weld for  
7 stress relief. I was thinking about the vessel  
8 itself.

9 DR. CAMPBELL: Oh, the whole vessel? I  
10 don't know the details of how they are going to  
11 relieve that.

12 DR. SHEWMON: A different question while  
13 I have got you interrupted. One place for galvanic  
14 problems is between the titanium and the steel. I  
15 don't see anything about how they are going to  
16 separate that.

17 DR. CAMPBELL: Well, it looks like it is  
18 resting on a steel beam, but I don't have the design.

19 DR. DIBELLA: There is a C-22 shoe on the  
20 bottom of the titanium drip shield.

21 DR. CAMPBELL: Could you identify  
22 yourself?

23 DR. DIBELLA: Carl DiBella, and I am with  
24 the NWTRB.

25 DR. CAMPBELL: So there is a C-22 shoe

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1 here, and then this has C-22 here. The point is that  
2 in the DOE models, this is the locus of stress  
3 corrosion cracking in their model, is at the lid,  
4 although what they do is that they treat it a little  
5 differently, in terms of allowing water to come into  
6 the package even through a stress growth cracking.

7 This basically shows the key flow paths  
8 in this scenario. Go ahead, Martin.

9 DR. STEINDLER: Let me go back to  
10 chemistry. The sense of the double-weld is only a  
11 delay find rather than an attempt to change chemistry;  
12 is that right? Is that the way that you see it?

13 DR. CAMPBELL: I think so.

14 DR. STEINDLER: All I am really asking is  
15 the difference between a single cover and a double  
16 cover is only in the time that it takes to penetrate  
17 the whole thing.

18 CHAIRMAN WYMER: I think that's right.

19 DR. STEINDLER: Rather than a shift in  
20 chemistries. So they don't have an interior plate  
21 with a different material?

22 CHAIRMAN WYMER: No, I think it is just to  
23 make sure that it stays closed.

24 DR. CRAGNOLINO: Could I make a  
25 clarification? Dr. Gustavo Cragnolino from the

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1 Center. They use to cover in order to have some sort  
2 of remedial action after the water, and the internal  
3 cover after being wet is going to be submitted to a  
4 process of shut pining, doing a reduced compression of  
5 stresses, and removing the potential for cracking the  
6 shield.

7 And while the second cover is going to be  
8 underneath that shield, and I think that is what they  
9 tried to make a distinction in terms of the  
10 construction. And answering to the question of the  
11 initial weld, the weight package, the outer container  
12 of Alloy 22, and --

13 DR. SHEWMON: Do you think the corrosion  
14 resistance would be better if they did it in air?

15 CHAIRMAN WYMER: Let's not engage the  
16 audience in a discussion.

17 DR. CRAGNOLINO: It is only for  
18 information purposes.

19 CHAIRMAN WYMER: That's fine, and I  
20 appreciate that, and don't hesitate to do that, but I  
21 don't want to get into a discussion.

22 DR. CRAGNOLINO: Okay.

23 DR. CAMPBELL: Okay. The key locations,  
24 in terms of the modeling, are the drips, gas and  
25 seepage drips, and so that essentially becomes what

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1 they call location one coming into the drip.

2 Another key location is the top of the  
3 drip shield, where drips are falling on to the drip  
4 shield. Initially for the first few hundred to few  
5 thousand years, this is hot. It is above boiling for  
6 the few hundred years.

7 So any water that would come back into the  
8 repository and drip on here would evaporate. And in  
9 fact I will show later that the temperature of this  
10 system is above ambient for many tens of thousands of  
11 years.

12 And for a long time it is tens of degrees  
13 above ambient. So there is always going to be a  
14 thermal radiant from the fuel rods out.

15 CHAIRMAN WYMER: You are going to have to  
16 kind of hurry, Andy, because you are running out of  
17 time.

18 DR. CAMPBELL: Okay. And the next  
19 location is the top of the waste package, and then  
20 location four is the waste forms themselves, and that  
21 includes the cladding. Location five is flow through  
22 the invert into the unsaturated zone underneath.

23 So those are the basic key modeling points  
24 that they are going to follow, and that we are going  
25 to be talking about in terms of water chemistry.

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1           This is their concept for general  
2 corrosion of the waste package, and general corrosion  
3 that causes failure in catches in the drip shield.  
4 There is humid air general corrosion after the  
5 humidity gets above a certain point.

6           I think that is around -- anything above  
7 50 percent. Once you get failure of the drip shield,  
8 you can get drips directly falling on the waste  
9 package, and it is generally thought that those drips  
10 would occur at the top of the waste package, or at  
11 least the most damaging ones.

12           And that's where they tend to model the  
13 formation of these general corrosion patches, and then  
14 you have stress corrosion cracking at the welds around  
15 the lid.

16           Again, this is all from TSPA, and this is  
17 their calculated temperature for various infiltration  
18 rates. You can see initially at closure the  
19 temperature goes up to about -- this is at the surface  
20 noise package, to a little less than 180 degrees  
21 centigrade.

22           And then decays away with time, and so  
23 that by 10,000 years, you are looking at temperatures,  
24 depending upon your infiltration rate, in the  
25 neighborhood of 50 degrees centigrade; and by about a

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1 hundred-thousand years, you have essentially decayed  
2 to ambient.

3 So even for long after the main thermal  
4 pulse is gone, you still have temperatures that are 10  
5 or 20 degrees above the ambient temperature.

6 DR. SHEWMON: What are the units on the  
7 various lines? Millimeters per year bin?

8 DR. CAMPBELL: Well, those are different -  
9 - and I don't have it here, but those are different.  
10 They divide the repository up into different bin  
11 infiltration, and each one has its own flux rate,  
12 depending upon the rock properties above it.

13 DR. SHEWMON: So is that millimeters of  
14 rock or millimeters of water?

15 DR. CAMPBELL: No, this is millimeters of  
16 infiltration.

17 DR. SHEWMON: Okay.

18 DR. CAMPBELL: So they are modeling a  
19 range of percolation rates.

20 DR. SHEWMON: I understand. You have  
21 answered the question.

22 DR. CAMPBELL: This is the cladding  
23 temperature and that is 350 there. So they are trying  
24 to keep the cladding temperature below 350 degrees.

25 This is what happens to relative humidity

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1 in the repository during the thermal pulse. It goes  
2 way down, and then comes back up. So even at a  
3 thousand years, you are above 80 percent relative  
4 humidity.

5 So clearly fairly early on, even while the  
6 packages are still warm, they are accumulating a film  
7 of water of them, but the humidity does not reach a  
8 hundred percent until close to a hundred-thousand  
9 years.

10 And this shows the percolation flux.  
11 During the thermal pulse, you are heating the rock up,  
12 and the idea of the current design is that the areas -  
13 - the distance between drips is about 80 or 85 meters,  
14 or something like that.

15 And the boiling front only reaches a few  
16 meters into the drip wall. But you are still going to  
17 be moving a fair bit of water around by heating up  
18 that amount of rock, because the rock is about 10  
19 percent by volume of water.

20 So there is a potential for a percolation  
21 flux during the thermal pulse, and one potential  
22 scenario is a reflux scenario, where some warm water  
23 can come back down through a fracture and come in on  
24 top of the drip shield, and possibly even get on to  
25 the way it is packaged.

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1 DR. STEINDLER: Can you go back to that  
2 relative humidity flux, or is that going to screw  
3 things up?

4 DR. CAMPBELL: Which flux?

5 DR. STEINDLER: The relative humidity.  
6 That's the one. I guess I am raising the point that  
7 reaching the relative humidity of a hundred percent at  
8 a hundred-thousand years, or whenever, is not  
9 particularly germane to the onset of chemistry.

10 DR. CAMPBELL: No.

11 DR. STEINDLER: Because you have got a  
12 significant film, and relative humidity is quite a bit  
13 below that.

14 DR. CAMPBELL: Essentially about 50  
15 percent.

16 DR. STEINDLER: Well, 50 may be a little  
17 low, but certainly a thousand to 5,000 years, you have  
18 got a significant amount of mineral movement in that  
19 thin film that goes on, and there is lots of  
20 experimental evidence that glass, if it were opened,  
21 begins to react pretty thoroughly at those  
22 temperatures.

23 And so we are talking a potential for  
24 glass reactions, if we are through it, at times that  
25 are less than the compliance time. That was my only

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1 point.

2 CHAIRMAN WYMER: Yes, and which is germane  
3 to chemistry.

4 DR. STEINDLER: Yes, I thought so.

5 DR. SHEWMON: When they got started on  
6 this a long time ago, they wanted to design it as a  
7 matter of policy for very hot fuel, but they haven't  
8 been putting it in, and they won't be putting it in  
9 until it is going to be a lot cooler.

10 Did they take that into account at all, or  
11 is this 300 degrees C limit gotten with very hot fuel?

12 DR. CAMPBELL: What they are going to do  
13 is blend. They are going to try and fix --

14 DR. SHEWMON: So do you think that is a  
15 reasonably realistic number?

16 DR. CAMPBELL: Yes.

17 DR. SHEWMON: Okay.

18 DR. CAMPBELL: And that' based upon --

19 DR. SHEWMON: Well, with the other limit,  
20 it looked pretty cold. You might change in other  
21 directions, which would be more damaging, but go  
22 ahead.

23 DR. CAMPBELL: What they plan to do is  
24 create a particular mix, in terms of putting waste  
25 packages -- because they are putting them end-to-end,

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1 they are going to determine the heat output for each  
2 package.

3 And then they are going to try and blend  
4 it in such a way --

5 DR. SHEWMON: You have answered the  
6 question. Thank you.

7 DR. CAMPBELL: -- to get a constant or  
8 relatively even distribution. Oh, let me back up.

9 CHAIRMAN WYMER: You are out of time,  
10 Andy.

11 DR. CAMPBELL: Okay. Well, let me make a  
12 couple of points here. What you see here, these  
13 increases, these are the increases in percolation flux  
14 due to the climate change model that they built into  
15 the system.

16 And basically what they are doing is that  
17 they are modeling an increase around 600 years, in  
18 terms of percolation flux, and then another one at  
19 about 2,000 years.

20 So they are modeling into this -- and this  
21 is pretty much based upon the Molenkavich cycles,  
22 which are the perturbations in the orbit of the earth,  
23 which are generally thought to control on a large  
24 scale going from glacial to inter-glacial periods.

25 That in about 2,000 years they are

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1 modeling an increase to a more glacial type of  
2 climate, and that will cause an increase in  
3 percolation flux. And you notice that that is really  
4 going to be the driver, in terms of the water.

5 This is a short duration event relatively  
6 speaking, and unless they have got this completely  
7 wrong, it is not that different than after about 2,000  
8 years, the high end of the percolation flux.

9 Now, of course, you can have the lower end  
10 of it, and that is much lower in terms of percolation.  
11 That's unreadable, but that is just a chemistry of  
12 basic major ion chemistry, and some minorized species  
13 for these various periods that they are modeling.

14 DR. STEINDLER: I think that table we  
15 ultimately need to recover again, because I think  
16 there is an important issue, and that is the little  
17 line that says additional constituents from complex  
18 thermal hydraulic chemical model. It is not used in  
19 the normal calculations.

20 CHAIRMAN WYMER: That was a point that I  
21 was going to make later.

22 DR. STEINDLER: That is the one that  
23 contains the fluoride.

24 CHAIRMAN WYMER: I will make a comment on  
25 that now. As far as I know, the Department of Energy

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1 is using the simple -- or what they call the  
2 simplified model because it seems to agree better  
3 with the experimental information that they have.

4           Whereas, the complex model doesn't, and to  
5 me that is a poor reason to use it. What they should  
6 do is understand why the complex model doesn't agree  
7 better than the simple model.

8           And obviously there is something bad or  
9 something wrong with the complex mode.

10           DR. STEINDLER: Or the experiments are not  
11 done right.

12           CHAIRMAN WYMER: There is always that,  
13 yes.

14           DR. STEINDLER: A simulated J-13 doesn't  
15 do much for me.

16           CHAIRMAN WYMER: That's true. Okay.  
17 Andy, finish up.

18           DR. CAMPBELL: This is just their  
19 conception model, and the way they model corrosion is  
20 they develop these for both the drip shield and the  
21 waste package, 300 square centimeter patches, at least  
22 for general corrosion.

23           So the concept is that you end up with  
24 patches that can allow evaporative water into the  
25 system, and again the same thing for the waste

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1 package.

2 Again, this is the general corrosion  
3 model, and that is one of a number of figures of  
4 general corrosion rates that are in the TSPA model.  
5 This is a CDF Alloy 22, with various variabilities.

6 And you are looking at corrosion rates  
7 that are between 10 to the minus 5, and 10 to the  
8 minus 4 millimeters per year on that scale, and that  
9 is for general corrosion.

10 And this is unreadable to everybody, but  
11 you have a copy on the last page, and these are just  
12 percent of packages breached. It is for the drip  
13 shield and the number of patch breaches per failed  
14 drip shield, and percent of waste packages, patch  
15 breaches, per failed waste package, and which is some  
16 measure of how many of these packages are failed. I  
17 don't have anything else --

18 DR. STEINDLER: But that is not a  
19 chemistry issue is it?

20 DR. CAMPBELL: No, this is a TSPA. This  
21 is an output from TSPA.

22 DR. STEINDLER: But what I am saying is  
23 that package failure per se does not attack  
24 immediately the question of what chemistry is inside  
25 the waste form. It is still on the outside.

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1 CHAIRMAN WYMER: That's right.

2 DR. SHEWMON: Some people could say the  
3 corrosion of the metal is a chemical question.

4 CHAIRMAN WYMER: I would say that. Okay.  
5 I think we are up to Paul here aren't we?

6 DR. SHEWMON: Okay. Well, a little  
7 philosophical comment at the start there; that if you  
8 pile enough conservative assumptions end-to-end, you  
9 can get an unreasonable answer.

10 Let me start with a story, a story about  
11 a King of India 1,600 years ago. He was a dutiful  
12 son, and he wanted to honor his father. They had a  
13 lot of good metallurgists around. So he put them all  
14 to work making a monument for his father.

15 And this turned out to be a 20 meter long,  
16 6 ton, bar of wrought iron. And they erected it  
17 outside of what is now Delhi, and has been there  
18 standing in the weather, monsoons every year, and a  
19 certain number of holy cows going by doing what holy  
20 cows do, a lot of dust.

21 And the column apparently hasn't rusted,  
22 and it has a patina on the outside of what a  
23 metallurgist might call coherent oxide, and it hasn't  
24 corroded like anything the rate that the models used  
25 in these documents that we are looking at would assume

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1 corrosion has occurred.

2 And so after 1,600 years the corrosion is  
3 quite slow. If we go back to under repository  
4 conditions, which were above water, and not too humid,  
5 a corrosion rate of Alloy 22 should be much slower  
6 than that of the Delhi column.

7 Yet the corrosion rate should be  
8 unmeasurably and unbearably slow, and yet the  
9 conservative DOE assumptions are that it goes at a  
10 rate which is appreciably faster than that of the  
11 wrought iron, at a rate characteristic of corrosion  
12 dissolution, driven by an applied voltage in deaerated  
13 salt water, strongly acidified.

14 I think that this is a mistake and that  
15 the engineering column is a good engineering analog,  
16 to use a phrase which is the DOE's, and that I will  
17 come back to later.

18 Now, to do something to find something to  
19 measure, the research people must find ways to compare  
20 alloys in time in which they can get results for their  
21 quarterly reports, and so they do this by devising  
22 tests under aggressive conditions which give  
23 dissolution, or cracking, or failure.

24 This stress corrosion test require a  
25 stress tending to pull the crack open. That is, there

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1 is an active stress in it, and in an aggressive  
2 environment.

3 And the aggressive environment they used  
4 in this sharply cracked, highly stressed, sample is to  
5 make it quite acid, dew point 7, and they put it in a  
6 boiling magnesium chloride and water mixture, about  
7 120 degrees C, and they can crack 316 in this, but  
8 they can't crack the 3-C-22. So they know that the C-  
9 22 is more resistant.

10 However, neither the stainless nor the C-  
11 22 shows cracking in hot acidified sodium chloride or  
12 lithium chloride solutions. And you know from our  
13 last meeting that if you raise the pressure, lower the  
14 Ph, add lead ions, and try like heck, you can indeed  
15 get stress corrosion cracking in the stainless C-22  
16 also.

17 I personally have difficulty seeing the  
18 relation of this, if any, to the performance of the  
19 waste containers in air in Yucca Mountain, but let's  
20 go on.

21 Crevice corrosion. Crevices often  
22 generate a more corrosive environment than flat  
23 surfaces. Differential aeration under water will give  
24 an anode or dissolution in a lower oxygen region of  
25 the alloy leading to localized attack.

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1 Chloride ion accentuates this in the  
2 nickel-chrome-iron-moly alloys of concern here.

3 The simulation test used here is to put two teflon  
4 washers in a deaerated chloride solution, heat the  
5 solution, apply a voltage until dissolution or  
6 corrosion occurs in the crevice.

7 The voltage is then reduced until  
8 passivation occurs. The minimum chloride concentration  
9 and voltage required for crevice corrosion to be  
10 initiated at a given temperature, like 95 degrees C,  
11 is higher for Alloy 22 than 316.

12 That is, it is more corrosion, or it is  
13 more resistant to crevice corrosion. Alloy 22  
14 exhibits passive behavior over a wide range of  
15 voltages, chloride ion concentration, and Ph in  
16 deaerated water.

17 There is no evidence of localized  
18 corrosion was detected. These are in experiments done  
19 by Cragolino. If the average corrosion current was  
20 measured with a steady applied voltage, and  
21 circulation to carry away the ions, the authors say  
22 the corrosion rate corresponds to a lifetime of 60 to  
23 80,000 years.

24 That is to remove the two millimeters  
25 thick wall of Alloy 22, and that is where these

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1 corrosion rates are obtained that we see, and led to  
2 the last perc that Andy showed. But that is in a cell  
3 with a voltage, and with extreme conditions, always  
4 under water, and always with a voltage applied.

5 This is not a best estimate, but a minimum  
6 estimate. The rate is increased by the reduced  
7 oxygen, the flowing salt water to remove ions, and the  
8 applied voltage.

9 Thus, a more realistic life, which  
10 actually will allow dry-out periodically, and didn't  
11 have all these things on it, would probably lead to a  
12 life that was appreciably longer.

13 Conclusions. I believe the DOE and NRC  
14 staffs have no sound scientific basis for their  
15 predictions of the rates of the corrosion of the waste  
16 package in the Yucca Mountain repository, and as a  
17 result have grossly overestimated the corrosion rates  
18 of the waste package.

19 The DOE claims, quote -- and this was in  
20 a letter that Andy sent us recently -- there is no  
21 information or analogs that exist on the performance  
22 of engineered materials for the necessary time frames  
23 of performance for the waste package.

24 I disagree and would suggest that  
25 conditions of the metallic iron nickel meteorites

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1 buried for a hundred-thousand to a hundred-million  
2 years in dry soil, or in Kansas or Iowa, which is not  
3 so dry.

4 And exhibit negligible corrosion provides  
5 a very good analog and strongly indicates that the  
6 rates of corrossions the DOE and the NRC staff have  
7 assumed for the waste package are too high by many  
8 orders of magnitude. Let's say a thousand for a round  
9 number.

10 The waste package should remain tight for  
11 at least a million years in Yucca Mountain, and this  
12 is without a drip shield. Now, the use of such a  
13 meteorite analog would be more accurate, yet  
14 conservative, since these iron nickel alloys would  
15 corrode much faster than Alloy 22 in the aggressive  
16 test DOE is using for guidance now.

17 Many of the Iron Nickel fragments are from  
18 inches to feet in size, and have been recovered from  
19 sites all over the world, and I have listed some  
20 there.

21 Some of these are wet and some are dry.  
22 I can see no use of such information in the reports  
23 put out by either of the groups we are reviewing. So  
24 I think what they have done by taking these cell  
25 measurements is put themselves into a world where they

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1 feel that they have to dissolve it somehow, and then  
2 they take that as the minimum rate for what they think  
3 they will find in nature. End of report.

4 CHAIRMAN WYMER: Okay. Let's talk about  
5 that. You think that is still true in the case of  
6 trace catalytic materials?

7 DR. SHEWMON: Well, there is lots of  
8 traces in wherever these things are buried. I mean,  
9 I don't know what meteor crater in Arizona is like,  
10 but the way the rainfall is, is probably the same or  
11 about as Yucca Mountain.

12 I wouldn't be surprised if what it is  
13 sitting in is about the same as Yucca Mountain, though  
14 I don't know the chemistry.

15 CHAIRMAN WYMER: So we would really have  
16 to know those things in order to make more than a  
17 qualitative comment about it?

18 DR. SHEWMON: You would, but there have  
19 been meteorites dug up that have been there for -- my  
20 Britannica, which was my reference on this -- a  
21 hundred-thousand years to a hundred-million years.

22 And some of these are in dry places, like  
23 Northern Australia or Southern United States, but some  
24 of them are pretty wet places.

25 CHAIRMAN WYMER: Well, they say -- DOE

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1 says that they take these very conservative positions  
2 and they assume these corrosion rates, which are much  
3 higher than they should be, and they still come out  
4 okay.

5 So do you think that there is perhaps a  
6 loss of credibility or believability in some sense  
7 because they are taking such an extremely conservative  
8 position?

9 DR. SHEWMON: Yes.

10 CHAIRMAN WYMER: And is this a negative or  
11 positive thing?

12 DR. SHEWMON: Well, I don't know. I think  
13 it is just wrong. It is whatever you want to use is  
14 a more polite way of saying that it is conservative.

15 But that was the point of my opening  
16 statement, which is that by striving always for  
17 conservative answers, in a chain-of-events, one can  
18 pile these on top of each other and find very  
19 unreasonable and unrealistic estimates.

20 CHAIRMAN WYMER: And that is one of the  
21 comments that -- for example, the advisory board has  
22 said that they haven't really come to grips with  
23 quantitatively evaluating the conservatism that they  
24 have in there in their system.

25 They have not really added it all together

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1 in a way that is understandable and credible.

2 DR. SHEWMON: In the reactor business, you  
3 try to get them to say best estimates, and nobody says  
4 best estimates here.

5 CHAIRMAN WYMER: And that is sort of a  
6 philosophical point of view as you said at the  
7 beginning, and something that has bothered me is that  
8 they keep coming out with the conclusion -- and  
9 probably right -- that the Alloy 22 will last a long,  
10 long time, and that corrosion will not be a big  
11 problem within 10,000 or maybe a hundred-thousand  
12 years.

13 But by taking these very conservative  
14 positions, they sacrifice something in believability,  
15 and I have not been able to decide whether I like that  
16 or not. I would like them to do a very realistic  
17 evaluation, and the best evaluation that they can, as  
18 it would be more believable.

19 And if they came up with a hundred-  
20 thousand years for the lifetime, then fine. That's  
21 sort of a million years. Great. But to come out with  
22 11,000 years, which is only a thousand years over the  
23 10,000 year limit, is somehow -- it sort of rubs me  
24 the wrong way.

25 DR. SHEWMON: And I don't know what the

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1 committee is going to do with this, or what they can  
2 do with it, since DOE is the one that is supposed to  
3 design it, and NRC comments, and you comment to NRC.

4 DR. STEINDLER: But therein exactly lies  
5 the problem. I don't recall reading -- and I don't  
6 claim to have read everything that NRC has written,  
7 but I don't recall NRC coming up with or the staff  
8 coming up with the same kind of general comments,  
9 saying to DOE that you guys have lost your mind.

10 You are way over-conservative on the  
11 lifetime of the metallic barriers. Now, maybe that is  
12 not their function. The other end of this thing is --

13 CHAIRMAN WYMER: And I suspect it's not.

14 DR. STEINDLER: -- that if the  
15 conservatism is adequate to meet whatever reasonable  
16 assurance ground rules that are used, then you don't  
17 care.

18 But I have another question, and that is  
19 whether is it feasible on the basis of experience to  
20 devise a catalytic corrosion process that would be  
21 accelerated greatly over what you have just indicated,  
22 and would those catalytic components have any chance  
23 of being in the drip water, which is moderately ill-  
24 defined as far as I can tell?

25 DR. SHEWMON: I think the catalytic

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1 components, we wouldn't use those words, but chloride  
2 would serve the function of accelerating the process.  
3 I guess you could call it a catalyst. It doesn't  
4 change its nature.

5 Fluoride is even worse. You will get to  
6 that perhaps in the titanium part, where it comes up  
7 more.

8 DR. STEINDLER: But let's focus in on  
9 Alloy 22. Well, besides the chloride, which we can  
10 argue about, depending on the concentration --

11 CHAIRMAN WYMER: Lead is the other one.

12 DR. STEINDLER: That's exactly the point.

13 DR. SHEWMON: Lead is the other one that  
14 comes up, but where they -- and I don't know what  
15 experiments with people like Gustavo are going to do  
16 with lead in place of the normal things.

17 But what they had for accelerator tests  
18 were such gosh awful pressures and temperatures, and  
19 so on, that --

20 CHAIRMAN WYMER: The question that you ask  
21 there, Paul, I think is what is the trade-off for  
22 extreme conditions for a short term test, and much  
23 milder conditions for a lot longer period of time, and  
24 that's what you have to try to get at.

25 DR. STEINDLER: It depends on how smart

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1 you are about the mechanism.

2 CHAIRMAN WYMER: Yes, and it does come  
3 down to mechanisms in my book always, and that is  
4 something that the Nuclear Waste Technical Advisory  
5 Board point they came up and that I agreed with, was  
6 that as best you can, you should determine what the  
7 mechanisms are because its only when you understand  
8 the mechanisms that you can extrapolate with  
9 confidence for the future.

10 And having said that, I will also say that  
11 I know that mechanisms in things like corrossions are  
12 extremely difficult to determine, the true fundamental  
13 mechanisms.

14 DR. STEINDLER: But the point that I am  
15 trying to make is -- and not very well, I guess --  
16 that while it may seem on the surface that one can  
17 throw rocks at DOE and hence the NRC staff for not  
18 objecting to this extreme conservatism, I wonder  
19 whether the uncertainty in relation to things like  
20 led, for example, isn't sufficiently large so that the  
21 conservatism used by DOE, and apparently accepted by  
22 NRC, is okay in terms of reasonable assurance.

23 DR. SHEWMON: But if you do that, what  
24 they have done is sort of put their head in a sack and  
25 -- or put a hand in the sack and pulled out a number,

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1 and said, gee, it is conservative, and so that must be  
2 better.

3 Maybe there is things that we don't know  
4 that I guess I sort of gave up the boogie man thesis  
5 some time back, and don't like to see it used here.

6 DR. STEINDLER: Well, corrosion is not my  
7 strong suit, and so I can't argue with you too  
8 successfully. I guess all I am trying to do is to  
9 defend, if that is a necessary term, defend the NRC  
10 staff from the charge that you guys have let the  
11 ultraconservatism of DOE slide past without objecting  
12 to it.

13 DR. SHEWMON: It seems to me that the  
14 meteorite thing --

15 CHAIRMAN WYMER: I don't know that they  
16 should object.

17 DR. SHEWMON: The meteorite thing has been  
18 in a variety of environments. I asked Andy about it,  
19 and he said, well, people have found smaller particles  
20 of this stuff inluvial mixtures and they are very  
21 corrosion resistant.

22 Now, relatively to what, I guess, but at  
23 least they are still there, and they haven't gone  
24 away.

25 DR. STEINDLER: Well, the trouble with

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1 those things is that you don't know what their  
2 conditions are that they have been subjected to over  
3 time.

4 DR. SHEWMON: But they dig these things up  
5 out of the ground, and in a wide variety of places.

6 DR. CAMPBELL: Has there ever been -- and  
7 are you aware of studies of corrosion rates of iron  
8 nickel meteorite fragments. I mean, that seems to me  
9 what you are saying here, is that that is a natural  
10 analog study that probably ought to be done.

11 DR. SHEWMON: No. But people have tramped  
12 around in the iron nickel alloy systems for a  
13 generation or two, and I am sure if there are more  
14 corrosion resistant than Alloy C-22 or even 316,  
15 stainless steel, we would have learned it.

16 It is not a novel system, and so it is  
17 more corrosion resistance than carbon steel, and  
18 probably more than wrought iron, but certainly not in  
19 chrome bearing high nickel alloys. That I am sure of.

20 CHAIRMAN WYMER: Well, DOE is in the  
21 unfortunate position of having to back up as best they  
22 can technically anything they say. You can sort of  
23 make these -- and pardon the expression -- handwaving  
24 arguments about, gee, this stuff is really corrosion  
25 resistant.

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1                   And it has been there a long, long time,  
2                   and it is similar material. But that doesn't cut it  
3                   as far as providing something in a document that they  
4                   can support scientifically and credibly to the  
5                   scientific community.

6                   DR. SHEWMON: They had looked for  
7                   engineering analogs that have been in business for  
8                   this long, and I think the meteorites are a superb  
9                   one. It is conservative, and it would corrode faster,  
10                  and it has been there for a hundred-million years in  
11                  some cases.

12                  CHAIRMAN WYMER: But what they don't know  
13                  though is what it would do under the controlled  
14                  conditions that they try to run these experiments at  
15                  relating to what they expect the repository conditions  
16                  to be.

17                  DR. SHEWMON: Well, what they run the  
18                  experiments at is not what they would find in a  
19                  repository. It is not in an electrohooded cell and  
20                  circulating in acidic chloride solutions, and that is  
21                  what bothers me.

22                  CHAIRMAN WYMER: Well, my impression of  
23                  that was that they were trying to find the potential  
24                  at which corrosion would start, and then were stating,  
25                  okay, those potentials are never reached in the

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1 repository. So that is sort of how the argument went  
2 as I understood it.

3 DR. CAMPBELL: Well, let me play devil's  
4 advocate a little bit here. The pillar of Delhi,  
5 which I don't know, but if it is in the area of India  
6 that I am thinking of, is probably subject to a  
7 monsoonal type environment.

8 DR. SHEWMON: That's right.

9 DR. CAMPBELL: Relative humidity may be  
10 significantly lower than most of the time frame for  
11 the repository in that environment. So it goes  
12 through these wetting and drying cycles, but during  
13 the wetting cycle, you are looking at a short duration  
14 event and then it dries out very rapidly.

15 So it is going to develop some sort of  
16 patina on it that becomes a barrier to further  
17 corrosion. We also don't know whether it was treated  
18 with anything that would help that.

19 DR. STEINDLER: Wait until you find out  
20 that somebody goes along and paints the fool thing  
21 every three years.

22 DR. SHEWMON: It has a fair amount of  
23 silicate inclusions that get hammered out in these  
24 things, which are thought to give wrought iron better  
25 than modern steel.

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1                   CHAIRMAN WYMER:   You have some factual  
2 information?

3                   DR. CRAGNOLINO:   Yes, I would like to  
4 provide some updated information on the New Delhi  
5 pillar. The New Delhi pillar was saved to sustain the  
6 condition -- and this is an important consideration,  
7 to know what that is, because essentially for as you  
8 said hundreds of years, and thousands of years, it was  
9 exposed to a relatively dry type of environment in New  
10 Delhi.

11                   Very low relative humidity, and I mean  
12 that it was perfect condition with oxidation in the  
13 air. However, there are now two peculiar concerns,  
14 the stability of the corrosion problem on the New  
15 Delhi pillar.

16                   And with the process of oxidation in  
17 India, and in particular in the areas surrounding New  
18 Delhi, the air has become polluted, polluted with  
19 industrial products.

20                   This is one problem. And this can be  
21 discussed in more detail, because the Indian people  
22 are very concerned over this, with the air impurities  
23 and people are concerned about it.

24                   The other problem that was called to the  
25 attention of -- and unfortunately he is not here to

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1 verify this in more detail, but the Indian people were  
2 going through a time and took advantage of the  
3 situation that the British came there.

4 And the British were concerned with this  
5 problem with -- and decided to build a concrete  
6 support, and in order to do the work better, they  
7 built a concrete support there.

8 Now, the particular problem is with the  
9 interface, and --

10 CHAIRMAN WYMER: Interfaces are always a  
11 problem.

12 DR. CRAGNOLINO: Yes. And this is a  
13 problem that they have, and there are people in India  
14 who are trying to grow away from this, and produce --  
15 and through the internet -- and I am making this story  
16 very long, but this is a fact -- got involved and he  
17 is providing technical support to these people.

18 CHAIRMAN WYMER: Well, I think we can  
19 conclude from all of this that the use of these  
20 analogs is probably only appropriate if they are  
21 tested under the relative conditions.

22 DR. CRAGNOLINO: In environment type  
23 conditions, and where they have very well defined  
24 conditions, and this is the moral that I get.

25 DR. SHEWMON: And do you take as these

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1 conditions underground someplace, or in the  
2 laboratory?

3 CHAIRMAN WYMER: Now, don't get me wrong,  
4 Paul. I think that these natural analogs are very  
5 suggestive of what will really happen. I don't think  
6 there is anything wrong with the general philosophy of  
7 what you are saying, except that I don't think that  
8 DOE can use them, and NRC can't use them either,  
9 unless they are more sharply scientifically defined.

10 Not that they may not be valid, but they  
11 will not be accepted I think is the point.

12 DR. STEINDLER: Well, I confess to a  
13 significant amount of confusion. Where are we?

14 CHAIRMAN WYMER: We are to my section of  
15 the agenda.

16 DR. STEINDLER: I know. We are seven  
17 minutes past that time.

18 CHAIRMAN WYMER: Well, I am going to catch  
19 us up, because I think that my discussion on the in-  
20 drift chemical environment, which I have prepared  
21 handouts for the group here that I will read through,  
22 are only designed to provide a factual -- a DOE  
23 factual basis.

24 DR. STEINDLER: No, what I was driving at  
25 was in the context of what you eventually want to put

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1 into a conclusion from this little exercise, do we all  
2 believe that in a sense chastising, mild or otherwise,  
3 both the Department of Energy, which is not I think  
4 your function, but certainly the staff, for allowing  
5 this extreme conservatism in corrosion rates to stand  
6 unchallenged is the question.

7 We don't have to decide it today, but I  
8 think that is the focus of the question.

9 CHAIRMAN WYMER: My view -- and we will  
10 discuss this and come up with a consensus, but my view  
11 is that extreme conservatism diminishes the  
12 believability of the analysis.

13 It doesn't necessarily impact whether or  
14 not the repository is going to hold the waste, because  
15 there are a lot of factors involved there, and it  
16 doesn't even necessarily negate the conclusions about  
17 the corrosion of the material.

18 But it diminishes your confidence in DOE's  
19 analysis, I think, and insofar as the NRC goes along  
20 with that, it diminishes my confidence in that. It is  
21 sort of similar to the arguments about whether or not  
22 the errors are acceptable in the analysis.

23 And whether or not the experiments are  
24 rungs that will get better results so that you can get  
25 some of the conservatism out of it. Now thee is a

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1 push right now to get better and better results so  
2 that there is less and less error in those results.

3 And while this may not affect the validity  
4 of the use of the repository, it does reduce the  
5 scientific credibility. It is philosophical as much  
6 as anything else, and I think we ought to at least  
7 comment on that, that there is a point there.

8 What it means is that they are not doing  
9 as tight a job as they should do, or as good of a job  
10 as they should do. We will wrangle about that.

11 DR. STEINDLER: We will argue about that  
12 later.

13 DR. CAMPBELL: Let me add a couple of  
14 things here as a seaway into your thing, into your  
15 segment, Ray, is that the NRC staff has to evaluate  
16 what DOE presents to them.

17 So inevitably, and because their goal is  
18 to be a regulator, they have got to focus on -- okay.  
19 DOE has given us this series of concepts, models,  
20 data, and so on, and we have to evaluate that in the  
21 context of what we know.

22 We can't go back to DOE and say, hey, you  
23 guys are nuts in terms of this conservatism that you  
24 built into the model. It is not NRC's position really  
25 to tell DOE to go back and redesign this, and get more

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1 realistic.

2 So they have to pretty much take it as it  
3 is given, and evaluate it in that context.

4 DR. STEINDLER: But you are saying that  
5 the evaluation can only be on one side. In other  
6 words, is the value too low is the only question they  
7 can ask. You can't ask the question is the value too  
8 high, which is what the issue is.

9 DR. CAMPBELL: They can if it gets into an  
10 issue of -- or in my opinion at least, and this is my  
11 opinion, if it gets into the area of challenging the  
12 whole concept of defense-in-depth, and that because of  
13 the conservatisms built in that you really don't have  
14 a handle on how other systems will --

15 DR. STEINDLER: You are moving me out of  
16 chemistry.

17 DR. CAMPBELL: Okay. Well, that is the  
18 question really, is can the NRC staff say that this is  
19 just too high.

20 CHAIRMAN WYMER: Well, I think it is an  
21 observation that we would make rather than a damning  
22 comment that we would make.

23 DR. STEINDLER: Well, let's not overlook  
24 the fact that there is uncertainty.

25 DR. CAMPBELL: Right.

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1 DR. STEINDLER: We have not, I think, said  
2 to the staff or to anybody else that this evaluation  
3 or the acceptance of the DOE position is wrong.  
4 Perhaps what I would call for is an enhanced  
5 commentary about the uncertainty on the corrosion.

6 CHAIRMAN WYMER: That might be a very  
7 appropriate thing.

8 DR. STEINDLER: I am still looking for  
9 some good answers to catalysis.

10 CHAIRMAN WYMER: It might be a very  
11 appropriate way to answer that.

12 DR. STEINDLER: And the uncertainly in  
13 their data has got to somehow temper the staff's  
14 approach to whatever DOE hands them. So I can argue  
15 on both sides actually.

16 I can argue that if the staff is given  
17 this extremely low corrosion rate to look at, and  
18 let's assume they hire somebody like Paul, who looks  
19 at the thing and advises them that this is an absurdly  
20 low high corrosion rate in relation to what the real  
21 world appears to be.

22 They have to add the uncertainties in the  
23 whole thing and say, look, we need reasonable  
24 assurance. So our window is a lot larger.

25 CHAIRMAN WYMER: Right.

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1 DR. CAMPBELL: Of course, along those  
2 lines, the key issue is going to be the environment  
3 inside and on top of the drip shield and the  
4 container, and the chemistry of this water coming in.  
5 And has DOE characterized the chemistry of this water  
6 and the chemistry on the surfaces of the drip shield  
7 and the waste package in a way that truly bounds the  
8 conditions that it will see.

9 I mean, you have cited the Delhi pillar,  
10 but as Gustavo has pointed out, conditions change, and  
11 the environment changes, and now instead of having  
12 this long lifetime, we are now probably looking at a  
13 relatively short lifetime if those conditions  
14 continue.

15 So one of the areas of uncertainty is how  
16 well, or how good a job have they done in terms of  
17 characterizing this environment right there, and that  
18 to me is the key to corrosion.

19 DR. SHEWMON: They always approximate it  
20 by an electrolytic cell, where they have got flowing  
21 solutions, and water all the time, and that just isn't  
22 the situation here.

23 The humidity may be 80 percent, but that  
24 is not flowing salt solution with an applied voltage.  
25 So go ahead.

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1                   CHAIRMAN WYMER: Well, pursuing just a  
2 little bit more my philosophical uneasiness. I feel  
3 the same uneasiness about the use of bounding  
4 conditions which are probably perfectly valid, and  
5 they do bound the conditions probably that could  
6 possibly exist.

7                   But if you use those instead of  
8 information that you could use to reduce the  
9 uncertainty, and so that that whole approach is not  
10 satisfying. It may be adequate, but it is not  
11 satisfying scientifically.

12                   But it doesn't mean that the conditions  
13 aren't bounded, because I think that they probably  
14 are.

15                   DR. STEINDLER: We are going to get into  
16 an argument about this.

17                   CHAIRMAN WYMER: Well, are you really?  
18 Okay. Let me -- I won't have a whole lot to say here  
19 because Andy in his opening comments, where he made a  
20 nice discussion of what the situation is, pretty well  
21 covered what I was going to say about the in-drift  
22 chemical environment.

23                   I will go down through a list of the TSPA  
24 model and what the extractions and processes relate to  
25 as they are relevant here. Down in the middle of the

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1 page there, the model ingrates these things more or  
2 less.

3 The water and cement reactions, gas and  
4 water, evaporation and condensation of water,  
5 precipitation and dissolution of salts, microbial  
6 action, which I think is a red herring, corrosion and  
7 degradation of EBS components.

8 Water in the invert, and water in the  
9 colloids, and these are things that the TSP model  
10 integrates. And the modeling period is divided into  
11 three regimes which are meant to simplify the model,  
12 and make it possible to do the calculations in a  
13 finite time.

14 And also trying to catch the periods  
15 during which major changes occur. And the first  
16 period that is looked at is 50 to a thousand years;  
17 and the second one is a thousand to 2,000 years; and  
18 the final one is 2,000 years to a hundred-thousand  
19 years, or more.

20 So they do try to capture in an overall  
21 way the time periods for which they examine what  
22 pertinent processes there are that are taking place,  
23 and what the temperature and humidity, and so on,  
24 conditions are that are relevant in those time  
25 periods.

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1           Now, one of the major criticisms that I  
2 have about the invert chemical environment is that  
3 they use simulated J-13 water, and I don't for the  
4 life of me know why they didn't go out to the well and  
5 full a couple of 55-gallon drums with water and use  
6 that instead of simulated material that does not  
7 necessarily have everything in it that was in the  
8 J-13 water.

9           And this gets to Marty's catalysis issue,  
10 these trace elements that are not necessarily included  
11 as simulated water. I think the simple fact of the  
12 matter is that we don't know what actual J-13 water  
13 would do, although there is a strong -- I have a  
14 strong feeling that it would not be a whole lot  
15 different from the simulated J-13.

16           But in fact I don't think we really know,  
17 and it seems to me that if you can experiment with the  
18 real stuff that you ought to.

19           DR. STEINDLER: You are defending the  
20 wrong groups here. In defense of the folks who do  
21 experiments, I would say in the last five years that  
22 they have used crushed tough calibrated J-13 water.

23           Now, you can argue that in the two --  
24 well, what they do is that they basically take J-13,  
25 and let it sit on crushed tough for two weeks, and

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1 filter it off.

2 And in the two weeks that they use to  
3 calibrate this stuff, you can argue that you may not  
4 be getting a full compliment at concentration. On the  
5 other hand, also recall, please, that J-13 is a  
6 simulation of what they expect in the repository, and  
7 whether that is a good simulation is another story.

8 And actual pore water, to get a pore  
9 water, is a real chore. I mean, the notion of a 55-  
10 gallon drum of pore water is a little bit difficult.  
11 Thirst water you may able to get away with, but pore  
12 water is tough to come by.

13 I am not nearly as unhappy about the use  
14 of simulated J-13 for a lot of experiments. It's when  
15 the concentration of the traces that they are looking  
16 at, which unfortunately happen to make some difference  
17 in the downstream answer of what this whole thing is  
18 about, is significantly lower than the normal trace  
19 composition of things that they have ignored. That's  
20 when I begin to at least wonder about it.

21 DR. CAMPBELL: One of the things that --  
22 and I thought I had sent them on to you, Ray, is one  
23 of the things that they have done with this simulated  
24 water is that they have these wonder ICP mass  
25 lectromers and other things that can do enormous

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1 amounts of data collection on every element that you  
2 can lay your hands on.

3 And apparently there are databases perhaps  
4 unpublished by DOE of the trace constituent in the  
5 waters that they used in the experiments. So even if  
6 you don't exactly have the water -- and it is a guess  
7 anyhow that it is from a J-13 well.

8 I mean, that is a guess that that would be  
9 something akin to or close to the actual water that  
10 would be essentially dripping on to the drip shield  
11 and waste package.

12 You have at least measurements of trace  
13 species in these waters that could be used to at least  
14 understand the impact at those concentration levels.

15 The real issue in my mind is have they  
16 characterized this environment well enough in their  
17 thought processes to have a good analog to what is  
18 going to be actually accumulating on the surface of  
19 the drip shield to the waste package.

20 And in my mind it is an evaporative  
21 environment for very long periods of time, and that  
22 you will tend to have fairly concentrated solutions on  
23 those surfaces.

24 CHAIRMAN WYMER: Well, I have a comment  
25 about that that I picked out of a report, a most

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1 recent report that I could get my hands on. It says  
2 that water evaporating into drips can lead to  
3 temporary accumulation of up to a few kilograms of  
4 soluble salt per meter of drip.

5 Now, that sounds like a lot to me,  
6 depending on the proximity of the repository, and to  
7 the repository center, and the infiltration rate.  
8 Edge locations had less salt accumulation because of  
9 less heat available.

10 And it goes on to say that salts would be  
11 deposited in the backfill, which they don't have  
12 anymore, but the report said this, and in the invert,  
13 and that seems to me to be a lot of soluble salt per  
14 meter.

15 DR. STEINDLER: But if you will look at  
16 the question of where is the soluble salt when in fact  
17 a cladding of the fuel is breached, which is when the  
18 rubber hits the rope.

19 My sense of following this down to the  
20 time interval is that the large accumulation of  
21 evaporates is gone.

22 CHAIRMAN WYMER: They expect it to go down  
23 beneath.

24 DR. STEINDLER: Right, and it is gone, and  
25 it has accumulated at least outside the waste form

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1 when the waste form begins to corrode.

2 CHAIRMAN WYMER: I think that's right.

3 DR. STEINDLER: That simplifies the  
4 corrosion picture a little bit, because you don't have  
5 to begin to guess at what the concentration of sodium  
6 nitrate is, for example.

7 CHAIRMAN WYMER: But it is suggestive that  
8 there might be some of these trace elements quite well  
9 concentrated.

10 DR. STEINDLER: Well, the problem comes  
11 under your domain, because it is going to pile up  
12 somewhere else. It may pile up somewhere else, and  
13 since I am looking at the in-waste form chemical  
14 dissolution issues, I don't have to deal with that I  
15 don't think in any significant fashion. But  
16 downstream in the unsaturated zone I may have to.

17 CHAIRMAN WYMER: Well, here is another  
18 comment that was made, and that is the redissolution  
19 of precipitates is difficult to model accurately  
20 because thermal chemical models lack data support for  
21 extreme concentration of temperature conditions  
22 because of the distribution of the flow in the EBS  
23 depends on change in backfill properties, which we can  
24 take out, and the nature of the seepage from the host  
25 rock, which we can't take out.

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1           So they are really saying in this  
2 particular report that they really can't model very  
3 well or accurately they say because they lack data.

4           DR. STEINDLER: This is the kinetics, you  
5 mean?

6           CHAIRMAN WYMER: This is for the buildup  
7 of concentration of the salts.

8           DR. STEINDLER: So it is kinetic issue and  
9 not a thermodynamic equilibrium issue?

10          DR. SHEWMON: It is easier to precipitate  
11 than it is to put it in solutions; is that what you  
12 are saying?

13          CHAIRMAN WYMER: Well, the redissolution  
14 of precipitates is difficult to model accurately,  
15 because thermo-chemical models lack data support for  
16 extreme concentrations. It just means that they get  
17 a precipitate, and then they put stuff on it that  
18 would change the nature of the precipitate, and they  
19 don't have the thermo-chemical data to see what those  
20 changes would be, what the nature would be after those  
21 changes.

22          DR. STEINDLER: And these are precipitates  
23 and not evaporates?

24          CHAIRMAN WYMER: These are precipitates  
25 and presumably it would be on the drip shield, or if

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1 that fails on the equation, the package; as well as in  
2 the invert and underneath the package.

3 DR. SHEWMON: If it dripped on to the  
4 shield and then the water went off as a vapor, is that  
5 an evaporate or a precipitate? It seems to me it  
6 could be both.

7 DR. STEINDLER: It is an evaporate.  
8 Precipitates are formed when you get uranium, and --  
9 well, when it is dissolved out of the fuel that now  
10 reacts with a whole bunch of other material, and you  
11 uranium and minerals.

12 That is a precipitation process and that  
13 becomes important because occasionally you precipitate  
14 things that you really don't want downstream.  
15 Plutonium, for example.

16 CHAIRMAN WYMER: Well, I do have a table  
17 here where they have made 19 separate analyses of J-13  
18 well water and then averaged them all to give you the  
19 -- and the analyses are pretty well --

20 DR. SHEWMON: Are these stimulants or the  
21 real thing?

22 CHAIRMAN WYMER: This is J-13 well water,  
23 and they analyzed for aluminum, boron, calcium,  
24 chlorine, fluorine, iron, bicarbonate potassium,  
25 lithium, magnesium, manganese, sodium, nitrate ion,

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1 phosphate ion, silicon sulfate and strontium.

2 DR. STEINDLER: And no fluoride.

3 CHAIRMAN WYMER: Yes, I mentioned  
4 fluoride. Fluoride is 4.4 milligrams per liter.

5 DR. CAMPBELL: That is an average, right?

6 CHAIRMAN WYMER: That is an average of 19  
7 separate analyses, which range anywhere from 2 to 2.7,  
8 depending on the analysis, but not bad. So that is  
9 about all I really wanted to say about that, because  
10 you have already seen quite a bit about it, and what  
11 Andy has done.

12 They have not really done the trace  
13 element of the analyses, and I do have some  
14 information about the lead content.

15 DR. STEINDLER: What is your view on the  
16 role of the cement that is holding the rock bolts in?

17 CHAIRMAN WYMER: That holds the rock bolts  
18 in?

19 DR. STEINDLER: Yes. Do you think it is  
20 important?

21 CHAIRMAN WYMER: I think it could be,  
22 depending on the location. One of the things that is  
23 important here that is not dealt with very well in the  
24 models because of the difficulty dealing with it is  
25 the microstructure of the thing.

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1           Suppose you have a couple of rock bolts  
2 grouted in directly above the waste package, and water  
3 drips out of those and reacts with the cement that is  
4 holding the rock bolts in?

5           They don't really catch that very well in  
6 the model. They catch it with respect to whether or  
7 not it ultimately winds up beneath the waste package  
8 and might lead to the plugging of fractures.

9           But they don't deal at all with the  
10 chemical environment that it might produce on the drip  
11 shield or on the waste package in these very awkward  
12 conditions, and the fact that it has a petition of the  
13 cement mixed with.

14           DR. STEINDLER: So the design by the  
15 Department of Energy should be that there are no rock  
16 bolts directly over the waste package?

17           CHAIRMAN WYMER: Just let the rocks fall.  
18 The heck with it.

19           DR. STEINDLER: No, just let the steel  
20 handle it, and just put the rock bolts on the side.

21           CHAIRMAN WYMER: Yeah. So that is sort of  
22 a minor point, but --

23           DR. CAMPBELL: Let's redesign the  
24 repository.

25           CHAIRMAN WYMER: Yes, but which is not our

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1 role here.

2 DR. STEINDLER: Well, I guess what I am  
3 trying to find out is whether or not you think that is  
4 a long enough issue so that it could begin to  
5 influence the corrosion rate of the fuel and glass,  
6 and all the other junk that is important?

7 CHAIRMAN WYMER: Well, I always come up  
8 against the fact that 10,000 years is a long time, and  
9 I certainly don't have any feeling for what these  
10 chemical effects that are not observable in the short  
11 term might be in 10,000 years.

12 My seat of the pants feeling is that I  
13 hope that it doesn't amount to much.

14 DR. STEINDLER: That isn't quite my point.

15 CHAIRMAN WYMER: What is your point?

16 DR. STEINDLER: My point is that if the  
17 corrosion of that grout, or whatever it is that they  
18 use, is done and over with, and all the rock bolts  
19 have fallen out in a sense, before the next bunch of  
20 water arrives at my waste form, I can argue that in  
21 terms of corrosion rate of the waste form, it doesn't  
22 make any difference.

23 CHAIRMAN WYMER: Yes.

24 DR. STEINDLER: Is that sustainable as far  
25 as you are concerned?

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1 CHAIRMAN WYMER: It is arguable, but I  
2 don't know if it is sustainable.

3 DR. STEINDLER: Anything is arguable. I  
4 have been there.

5 CHAIRMAN WYMER: Again, that is an  
6 argument that lacks factual --

7 DR. CAMPBELL: One of the things that I  
8 came across, and I can't recall exactly where it was,  
9 and maybe it was in the IRSR, but maybe it was in one  
10 of the DOE documents, was that they are going to look  
11 at evaporative processes and the effects on chemistry,  
12 and they are looking at those.

13 The scenarios right now don't necessarily  
14 take into account evaporative processes when they are  
15 calculating the solubles or the mobilization from the  
16 waste form.

17 And in fact they have a pretty wet  
18 environment that occurs, but that is your topic of  
19 discussion.

20 CHAIRMAN WYMER: Well, the environment on  
21 the waste package is a separate discussion.

22 DR. CAMPBELL: But I think what we have  
23 identified here is an issue that the chemistry on the  
24 waste package is still highly uncertain, and probably  
25 needs to be defined better in terms of the scenarios,

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1 or waste package and drip shield corrosion, and then  
2 ultimately --

3 CHAIRMAN WYMER: Because of uncertainties  
4 in the chemistry of the water that hits the waste  
5 package.

6 DR. CAMPBELL: Because of that, and  
7 because of the uncertainties in the scenarios in which  
8 you have water on the drip shield and waste package,  
9 and whether it be a film of water most of the time,  
10 with occasional drips, and how those two different  
11 scenarios can play out with time.

12 And you have basically -- and let's ignore  
13 that the load humidity, high temperature regime that  
14 is relatively short in duration for the time being,  
15 although you need to look at that in terms of a couple  
16 of processes --thermo-hydraulic, chemical, and a  
17 couple of other processes.

18 But for the longer term, the main concerns  
19 are what are the long term chemistry for this moisture  
20 film on these two barriers, and then what is the  
21 impact of water dripping on to those barriers.

22 DR. STEINDLER: Do you get the impression  
23 that the NRC staff is ignoring that issue?

24 DR. CAMPBELL: No, not at all.

25 DR. STEINDLER: So they are as unhappy or

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1 as concerned about that as we might be or that we seem  
2 to be?

3 DR. CAMPBELL: It is one of their issue  
4 areas, yes.

5 CHAIRMAN WYMER: I think there are  
6 practically no issues that we could think about or  
7 talk about that haven't been considered and discussed.

8 DR. STEINDLER: Well, that's my view, and  
9 I just wondered what they are coming up with.

10 CHAIRMAN WYMER: There isn't anything that  
11 hasn't already been thought about and discussed at  
12 some length by the staff. I think that is certainly  
13 true. And I have some other comments along that line,  
14 but I will save those until a little bit later.

15 But I think the issues have been  
16 thoroughly thought of, and whether or not the  
17 experimental information is adequate to do the issues  
18 that have been obtained is a question, and that is a  
19 matter of sources more than anything else.

20 Well, let's push on here, and there are  
21 other things that will come up as we go along. Let's  
22 talk about taking a break.

23 DR. CAMPBELL: That sounds like a good  
24 idea.

25 DR. CRAGNOLINO: May I provide some

1 information about natural analogs for --

2 DR. CAMPBELL: Make it short.

3 CHAIRMAN WYMER: Let's defer it if you  
4 don't mind. I want to hear it. Anything you want to  
5 say is relevant. Keep it in mind and we will get to  
6 it. Let's take a break and come back at a quarter  
7 after.

8 (Whereupon, a recess was taken at 10:03  
9 a.m. and the meeting was resumed at 10:17 a.m.)

10 CHAIRMAN WYMER: All right. Let's start.  
11 I guess you are up again, Paul, on Titanium alloy  
12 corrosion.

13 DR. SHEWMON: Okay. I was surprised to  
14 find out that this thing is a 15 millimeter drip  
15 shield, which is a respectable piece of titanium. It  
16 is Grade 7, which has 2/10s percent palladium added to  
17 it to help avoid hydrogen going into solutions in the  
18 metal.

19 The alloys proposed for Yucca Mountain  
20 -- well, okay, because this catalyzes the hydrogen and  
21 reduces the hydrogen pickup, and Gustavo says it helps  
22 or works, and so I will take his word for it.

23 Titanium is quite corrosion resistant in  
24 air, water, and sea water. They build ships out of it  
25 and have not had any trouble with it. Passivation

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1 under water occurs in hours to days, and titanium is  
2 active, and so contact with iron will give an  
3 electrolysis of water.

4 And it would seem to me that in air that  
5 titanium would last forever, but there is no  
6 engineering analogs, and so they make conservative  
7 assumptions.

8 With an applied voltage, as you might get  
9 from the galvanic corrosion with iron, you can  
10 -- the titanium can be made to dissolve in chloride  
11 solutions and dissolve faster in fluoride, plus  
12 fluoride solutions.

13 There is little tendency to crevice or  
14 localize corrosion, and so they are interested in  
15 general corrosion. There is reasonable talk about  
16 hydrogen embrittlement, and the outline that I got  
17 from Andy suggested that I talk about this  
18 particularly.

19 So let me talk about hydrogen induced  
20 cracking. I find in the NRC notes that this can occur  
21 only if you have all three of the following. You have  
22 to have some potential which will tend to make the  
23 water break up in the contact with titanium, and  
24 galvanic voltage is enough for this.

25 You must be above 80 degrees C, or else

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1 the hydrogen won't diffuse into the titanium, and you  
2 have to be at either acidic or basic, less than 3 or  
3 greater than 12 Ph.

4 Hydrogen induced cracking occurs in  
5 engineering applications like aircraft. I don't think  
6 it will happen here, but let me tell you why. Where  
7 it occurs is in high strength alloys with sharp  
8 notches and high stresses.

9 They then get tearing and the tearing can  
10 be accelerated by a generation of some titanium oxide  
11 and hydrogen that is free to go into the metal.

12 And so you end up with an accelerated  
13 crack growth under applied stresses. But the stresses  
14 and the notches are minimal in the drip shield. The  
15 roof collapse could cause this, but many of these  
16 stresses would be compressive.

17 Thus, it is difficult to see how hydrogen  
18 induced cracking could be a concern. Let me emphasize  
19 -- well, okay. I find this hard to give credence to  
20 because the phenomenon never gives spontaneous  
21 cracking or indeed fragmentation of the drip shield.

22 What it means is that it is not as hard to  
23 drive a crack through it when you have applied stress  
24 and you are tearing something apart. I don't see how  
25 there can be the substantial stresses and strains in

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1 this geometry that are required, and so it seems to me  
2 that hydrogen-induced cracking is really something  
3 that would be absent.

4 But then I have got it summarized here.  
5 Cracks in Titanium are absent, crack opening stresses  
6 are absent; water, required for hydrogen charging, is  
7 rare and transient.

8 But the AMR says they know all this, but  
9 assume that it fragments anyway just to be  
10 conservative. So how can you argue with conservatism.

11 CHAIRMAN WYMER: And that gets back to  
12 this same philosophical question that we have been  
13 raising periodically here, which is to what extent  
14 does that give you a feeling of disquiet.

15 It is contrary to the scientific method,  
16 but it probably is a safe and conservative way to go,  
17 which really doesn't challenge the viability of the  
18 repository.

19 DR. SHEWMON: And they also go back to the  
20 general corrosion, which again they get out of a  
21 galvanic cell with circulating fluids, and aggressive  
22 media, and that then is taken as a bound on what could  
23 be the general corrosion rate.

24 CHAIRMAN WYMER: My reading on everything  
25 that you have been saying so far, Paul, is that you

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1 think that they are very conservative, and that  
2 actually there will be no significant corrosion  
3 problems in a 10,000 year time period. Is that a fair  
4 assessment of your position?

5 DR. SHEWMON: Yes. At least 10,000.

6 DR. STEINDLER: You don't think there is  
7 an electrolytic problem at the foot of this thing?

8 DR. SHEWMON: There is certainly the  
9 potential for galvanic cell there, but even if you  
10 broke it up there, the shield still functions.

11 CHAIRMAN WYMER: Now, suppose you had a  
12 couple of rock bolts that were cemented and grouted  
13 in, and the grout slowly over time -- and we have got  
14 a lot of time here -- dissolved and ran off the drip  
15 shield like the picture shows there, and combined at  
16 the foot of the drip shield, where it rests on the  
17 Alloy 22.

18 And how you have got these cement  
19 ingredients there. Does that not change the picture  
20 considerably, and does that not make it desirable to  
21 have some sort of an experimental analysis of that  
22 condition?

23 DR. SHEWMON: Well, if we are talking  
24 about hydrogen embrittlement, the question and the  
25 criteria that I have got at the top would be does it

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1 change the Ph to be low or high.

2 CHAIRMAN WYMER: Well, is hydrogen  
3 embrittlement the only thing we should concern  
4 ourselves with?

5 DR. SHEWMON: Well, that is the voltage  
6 driven problem that you have down at the bottom, yeah.  
7 Up at the top, you have got general corrosion and it  
8 is not under water. And I don't see how it could stay  
9 under water.

10 CHAIRMAN WYMER: Well, it wouldn't be  
11 emersed, but it would presumably have a film of water.

12 DR. SHEWMON: Yes, and is that an  
13 effective electrolytic media that will carry away ions  
14 easily?

15 CHAIRMAN WYMER: Yes.

16 DR. SHEWMON: Okay.

17 DR. STEINDLER: Especially in high  
18 amenities where you have got more than a couple of  
19 monolayers, and we have made minerals on glass that  
20 way very fast.

21 DR. SHEWMON: Well, then maybe you could  
22 get some general corrosion up there. I don't know  
23 what the applied voltage would come from, but the  
24 transport media is there.

25 This thing is not allowed to dry out. We

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1 have got enough source of water in the surrounding  
2 soil so that it is not dry like the surface. It is  
3 always wet or saturated.

4 DR. CAMPBELL: In the absence of air  
5 circulation through the repository, the natural  
6 condition is to approach a hundred percent, or to go  
7 to a hundred percent humidity.

8 And once they close it up -- as long as it  
9 is open and they are circulating air through the  
10 system, they are drying it out and they are keeping it  
11 dry. And that is more analogous to these analogs,  
12 where you have a dry environment that occasionally  
13 gets some moisture on it, but by in large is dry.

14 Or, for example, archeological artifacts  
15 that are in caves in Nevada that are dated at almost  
16 10,000 years, because of those dry environments, they  
17 tend to be preserved.

18 But once you close the repository up,  
19 there is enough water and moisture in the rock, and  
20 percolation flux, that the air trapped in there will  
21 go to about a hundred percent humidity, except during  
22 this thermal pulse, when you are driving that moisture  
23 away.

24 DR. SHEWMON: But you still need something  
25 to drive this, and it is corrosion resistance, and

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1 more corrosion resistant than meteorites.

2 Now, if you have got a voltage applied,  
3 yes, but if you haven't, then you get back to whether  
4 that is realistic, and do you corrode through that  
5 fast. And I guess it could be, but I have trouble  
6 believing it.

7 CHAIRMAN WYMER: What happens if the --  
8 you probably can't answer this, but let's talk about  
9 it. But what happens if, let's say, the basis did  
10 corrode away to the point where the drip shield sat on  
11 top of the Alloy 22? What about that interface? Are  
12 there any galvanic problems there?

13 DR. SHEWMON: I suppose if you have got  
14 monolayers of water there, but then you have to get to  
15 these other criteria, and by that time is the  
16 temperature above 80 C? Is there something that would  
17 make the Ph high or low?

18 I am not sure that hydrogen charging would  
19 be your problem. There maybe some galvanic corrosion  
20 and dissolution, and the titanium has to get carried  
21 away.

22 DR. CAMPBELL: And by high, you mean above  
23 10 or 11?

24 DR. SHEWMON: Well, 12 is what it says in  
25 the NRC report I got.

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1 DR. CAMPBELL: So, 12, and cement pore  
2 water type of pHs to get into that range. I mean, one  
3 of the scenarios that really doesn't show is that with  
4 time the supports are going to corrode and lose their  
5 strength.

6 DR. SHEWMON: Which supports?

7 DR. CAMPBELL: The drip supports, and so  
8 you could have not only rock fall, but you could have  
9 over longer periods of time --

10 CHAIRMAN WYMER: A collapse of the  
11 support?

12 DR. CAMPBELL: Yes, a collapse of the  
13 support on top of, or a rock fall falling out and  
14 flying on top of the drip shield. Eventually you are  
15 going to have bangs and dents, and material on top.

16 DR. SHEWMON: That might influence the  
17 general corrosion. I don't think it will give  
18 hydrogen cracking, because even if you have the  
19 hydrogen there, if you have not got a stress and  
20 strain to drive it, you won't break it up.

21 CHAIRMAN WYMER: Is hydrogen a pretty key  
22 issue with respect to the titanium?

23 DR. CAMPBELL: Not with general corrosion.  
24 It is with the hydrogen induced cracking.

25 CHAIRMAN WYMER: Sure, but we are talking

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1 more broadly than that. That is one of the issues.

2 DR. SHEWMON: Well, I am trying to  
3 differentiate the two, and say that the hydrogen  
4 cracking, which they assume will occur, I don't see  
5 how it can. The general corrosion could well be  
6 driven by the galvanic or accelerator.

7 DR. CAMPBELL: Because of the environment  
8 there, where would the hydrogen come from?

9 DR. SHEWMON: Water.

10 DR. CAMPBELL: But you have an oxidizing  
11 environment.

12 DR. SHEWMON: The titanium is active  
13 enough to take the oxygen from the water.

14 DR. CAMPBELL: So the titanium itself is  
15 going to act as the catalyst to generate it?

16 DR. SHEWMON: It is going to act as a  
17 getter, but if it is going to get past the surface of  
18 the titanium, it has to be hot or warm.

19 CHAIRMAN WYMER: And alkyl generally chews  
20 away at these oxide protected coasts doesn't it?

21 DR. SHEWMON: It can, yes.

22 CHAIRMAN WYMER: At the risk of  
23 randomizing our discussion here, let me ask Andy if he  
24 will show that view graph about the temperatures of a  
25 function of time again.

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1 Well, okay. We did in previous meetings  
2 talk about this temperature regime, where corrosion  
3 can take place in a regime, and if it gets hotter than  
4 that, it dries out. And if it gets colder than that,  
5 then it is kinetically too slow to make any  
6 difference.

7 So there is a regime of temperature and it  
8 looks to me like for the first -- well, sort of like  
9 for the first 80 or so years you are in that regime.  
10 And then you get into it again after a couple of  
11 hundred years, and you stay in it for a few hundred  
12 years.

13 DR. SHEWMON: What causes the spike, and  
14 where are we measuring this temperature?

15 CHAIRMAN WYMER: The circulating arrow.

16 DR. CAMPBELL: If the spike comes from  
17 closing up the drips, or closing up the repository,  
18 when you cut off the ventilation and close it up, then  
19 you will get that spike in temperature.

20 In fact, the temperatures prior to that  
21 are probably not very realistic the way that they  
22 calculated them.

23 CHAIRMAN WYMER: There are hundreds of  
24 years, and maybe thousands of years, where the  
25 temperature is in the corrosive temperature range, if

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1 that regime is a true regime, and people seem to think  
2 that it is.

3 DR. STEINDLER: Above 80 degrees, is that  
4 what you are saying?

5 DR. CAMPBELL: Yes. My recollection is  
6 that that was something that was brought up in our EBS  
7 working group 2-1/2 years ago, and that that was, I  
8 believe, crevice corrosion that they were concerned  
9 about.

10 DR. SHEWMON: In titanium?

11 DR. CAMPBELL: No, no, no.

12 CHAIRMAN WYMER: That's why I said I am  
13 randomizing the discussion, Paul. But I neglected to  
14 bring it up when you were talking about that. So I  
15 think in fact that there is a temperature regime is  
16 important, and the fact that you are in it for pretty  
17 long periods of time potentially here is important.

18 DR. CAMPBELL: I may have a view graph of  
19 the --

20 CHAIRMAN WYMER: It's not as though you  
21 are out of the regime for most of the time.

22 DR. CAMPBELL: The temperature on the drip  
23 shield.

24 DR. STEINDLER: On the C-22 or the drip  
25 shield?

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1 DR. CAMPBELL: On the drip shield.

2 CHAIRMAN WYMER: Well, the C-22 though is  
3 what we really care about. That is where the  
4 temperature regime was discussed as being relevant.  
5 So we are not nailing it down too tightly here, but  
6 the drip shield is not going to be a whole lot  
7 different from the Alloy 22.

8 DR. CAMPBELL: The peak in temperature  
9 there, the solid line, is the alloy or the waste  
10 package, and the dotted line just below it is the drip  
11 wall temperature. So the drip shield is probably not  
12 going to be that different than the waste package  
13 itself.

14 CHAIRMAN WYMER: That is very similar to  
15 the graph that you just showed and it tracks it pretty  
16 well.

17 DR. CAMPBELL: Yes. This is just one  
18 slice of that, one of the bins.

19 CHAIRMAN WYMER: The first 80 or 90 year,  
20 you are in that regime, and then you get into it again  
21 after about a thousand years.

22 DR. CAMPBELL: Now, 5 meters above the  
23 crown of the drip, these are the temperatures, and so  
24 you get a very strong radiant from the drip wall to a  
25 few meters in.

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1 CHAIRMAN WYMER: Well, the only point I  
2 wanted to make in bringing this up was we are in the  
3 corrosion regime for it for quite a while. That was  
4 the only point, and so we can proceed to talk about  
5 titanium again.

6 DR. CAMPBELL: Paul, what are the key  
7 issues in your mind in terms of more general corrosion  
8 effects on titanium and the uncertainties of that.

9 DR. SHEWMON: No. I think they are  
10 probably more credible than the C-22, because it is an  
11 active material, and you have got water, and it is in  
12 the discussions of how protective the oxide layer is  
13 over these long periods of time. And there is no  
14 analog, and I don't know, but it may indeed be true.

15 CHAIRMAN WYMER: Were you able to  
16 determine from what you read whether or not it is the  
17 position of DOE that the titanium drip shield will  
18 last 10,000 years or longer?

19 DR. CAMPBELL: It's longer.

20 DR. SHEWMON: Yes. He gave something  
21 there, and it started up in the 20,000 year period as  
22 I recall. I don't know whether that --

23 DR. CAMPBELL: The last line.

24 DR. SHEWMON: And that is all general  
25 corrosion; is that right?

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1 DR. STEINDLER: What do you mean by less?

2 DR. SHEWMON: Maintain some --

3 DR. STEINDLER: Well, all I need is a  
4 small hole for liquid to get into my waste package and  
5 begin that process. I don't have to collapse the  
6 whole shield.

7 DR. SHEWMON: Well, I don't think that  
8 once you get past the titanium shield that you are  
9 going to go through the C-22 as fast as you do the  
10 titanium.

11 DR. STEINDLER: Okay. Well, at least the  
12 point is that is where you start counting, in terms of  
13 time.

14 CHAIRMAN WYMER: Now, what would lead to  
15 a hole, something like a rock bolt dropping and  
16 denting it?

17 DR. STEINDLER: No, no, no.

18 CHAIRMAN WYMER: And wouldn't that be an  
19 enhanced corrosion area to lead to a hole?

20 DR. STEINDLER: No. You get uniform  
21 corrosion smoothly?

22 CHAIRMAN WYMER: I don't know. That's the  
23 issue.

24 DR. SHEWMON: Done with statistics.

25 DR. STEINDLER: Done with statistics?

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1 Okay. Well, that takes care of me.

2 DR. SHEWMON: I don't know what they do to  
3 get their randoms. It is too large a spectrum and  
4 conditions, I guess.

5 DR. STEINDLER: I am trying to see how old  
6 my fuel is before somebody finally says, okay, you  
7 have got water dripping on your oxide.

8 DR. CAMPBELL: In the last graph on the  
9 view graphs that I handed out, those are the kinds of  
10 time frames for the top one, and that is from TSPA.

11 DR. STEINDLER: And I didn't understand it  
12 there either. Fraction corrosion failure.

13 DR. CAMPBELL: Well, I wrote that just to  
14 try and summarize what these slides are showing, but  
15 these are the various percentiles for failure on a  
16 drip shield.

17 DR. STEINDLER: Well, I can argue that we  
18 ought to be looking at 10 or 20 percent breaches since  
19 it is statistical. And at 10 or 20 percent, I now  
20 find that I am dripping on my waste package.

21 And pretty soon the waste package is going  
22 to have 10 or 20 percent penetration, and again  
23 statistical since you guys in the corrosion business  
24 seem to be entirely statistical.

25 I am still trying to find out -- and in

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1 effect I don't care about the time particularly,  
2 because we are well past the compliance time, but I am  
3 interested in the temperature.

4 If the only thing I have to deal with --  
5 and I am focusing in on the waste package, but if the  
6 only thing I have to deal with is reasonable  
7 solutions, ground water, et cetera, dropping on 25  
8 degrees centigrade and irradiated at 102, that is one  
9 thing.

10 If I have to worry about the thing being  
11 150 degrees initially, I get a somewhat different  
12 answer.

13 CHAIRMAN WYMER: And you have to be  
14 concerned --

15 DR. STEINDLER: Especially in the gap  
16 release and the release of material in the grain  
17 boundaries.

18 DR. SHEWMON: You can go out to 10,000  
19 years here, and you are down to 40 degrees centigrade.

20 DR. STEINDLER: So you think I am safe  
21 that length of time?

22 DR. SHEWMON: Well, I don't know about  
23 that, but I think you are quite below temperature by  
24 the time that the liquid comes in contact with it.

25 CHAIRMAN WYMER: Well, what kind of

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1 activation energies for the corrosion process are we  
2 talking about? How steep is the curve for the  
3 temperature?

4 DR. SHEWMON: Well, anything that is  
5 active at these temperatures has to be some process  
6 which has a low activation energy, because everything  
7 with a high activation energy doesn't work anymore.

8 So what the source of hydration steps they  
9 come in contact with, or are going on here, I don't  
10 know. But I think the activation energy isn't a  
11 useful way to get at it, because there has to be  
12 different processes with a spectrum, and the high  
13 activation energies won't go, period. You're out.

14 CHAIRMAN WYMER: It depends on where it  
15 is.

16 DR. SHEWMON: I am very familiar with that  
17 sort of thing. We could ask, but I don't think they  
18 would find it too useful. They do find hotter  
19 solutions go faster.

20 CHAIRMAN WYMER: Well, if you do have  
21 different mechanisms at different temperatures, then  
22 of course all bets are off.

23 DR. SHEWMON: Well, you do have different  
24 mechanisms.

25 DR. STEINDLER: Do I get dissolved

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1 titanium dripping on my outer end waste package?

2 DR. SHEWMON: Yes. Conservation of matter  
3 is our policy.

4 CHAIRMAN WYMER: Not if you look at the  
5 models carefully.

6 DR. SHEWMON: Oh, okay.

7 CHAIRMAN WYMER: Which is another issue  
8 for another day.

9 DR. STEINDLER: What sort of  
10 concentrations would you expect? Well, are we looking  
11 at the solubility of  $TiO_2$ , too? Is that the limit?

12 DR. SHEWMON: Well, is there titanium  
13 hydroxide? And whatever it is, we are carrying it  
14 away in this demolecular lader, and it builds up  
15 someplace. And 15 millimeters is a lot of titanium.  
16 That is one of my complaints with the electrolytic  
17 cell business.

18 It always gets the products away, and  
19 washes it away so that you never get into the buildup  
20 of this barrier that happens in the real world.

21 CHAIRMAN WYMER: One of the complexities  
22 of this whole thing that makes it so hard to grapple  
23 with, and I am sure the staff and everybody else has  
24 had the same problem, is this time dependent factor.

25 If things happen early, and if something

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1 really goes badly wrong, which is not expected, but if  
2 it does, the first few hundred to a thousand years or  
3 so, then you don't necessarily have an oxidizing  
4 environment, because you have a hell of a lot of iron  
5 in this repository.

6 And until it is oxidized, you have a  
7 reducing environment, and titanium, of course, as it  
8 dissolves first, it is Titanium-3, which is a powerful  
9 reducing agent. It is a strong reducing agent.

10 And then you have, of course, you have  
11 ferris ions. So if something does happen early before  
12 all the oxygen depleting materials are used up, then  
13 it is a reducing environment.

14 And that is not what has been considered  
15 in any of these considerations. Now, it is unlikely  
16 that anything will happen in these early stages while  
17 there still is iron around in a reducing environment.  
18 But if it were to happen, then this is a totally new  
19 ball game.

20 DR. SHEWMON: I don't think it is unlikely  
21 at all. I think it is highly likely. Unless you  
22 expect the world to corrode nice and uniform across  
23 this whole thing, and the cladding and all the rest of  
24 the stuff immediately disappears as the water attacks  
25 the actual waste form, which sounds to me to be even

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1 more of a ridiculous conservative approach, I think  
2 you have a real chance of at least a portion of the  
3 corrosive attack on the fuel in the glass to be in a  
4 non-oxidizing environment.

5 CHAIRMAN WYMER: Yes, there is a  
6 possibility.

7 DR. SHEWMON: And I will raise that issue  
8 eventually.

9 CHAIRMAN WYMER: But certainly not uniform  
10 corrosion is an issue here. We are all familiar with  
11 the fact -- and to be simplistic -- that when we drive  
12 our cars through the salt in the winter that the whole  
13 car doesn't corrode. It corrodes around the running  
14 board and under the fenders, and of the joints.

15 So non-uniform corrosion is well known,  
16 but that is under conditions where you have non-  
17 uniform conditions of the surface, and the metal, and  
18 we have some of that here.

19 DR. STEINDLER: Well, you do have some of  
20 that, that's right.

21 DR. SHEWMON: Let me bring up something  
22 different, and I guess it has to do with the  
23 permeability of the earth over this mine, which some  
24 of you may know more about than I do.

25 But I remember going out to Arizona a long

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1 time ago in a different incarnation almost, and  
2 somebody was studying air coming out of vents in the  
3 ground, and they didn't know where it went in, but  
4 they knew it slowly came out here.

5 And I guess the thing that I carried away  
6 from that is that the air, or the earth above this is  
7 permeable. There are passage ways through it. Radon  
8 does come up in our basement out of the ground or  
9 whatever.

10 And is that over these times fast enough  
11 to counteract this reducing environment that you talk  
12 about, or is there anything done on that?

13 CHAIRMAN WYMER: Well, the oxidizing  
14 environment is assumed entirely to be due to oxygen in  
15 the air and in the water that comes into the drip. It  
16 is not really considered to be necessarily anyplace  
17 else.

18 DR. SHEWMON: But we are talking about  
19 after this is closed up. The air can still come into  
20 the drip then?

21 DR. STEINDLER: Yes, debris.

22 DR. CAMPBELL: They have done a fair  
23 number of air permeability studies.

24 DR. SHEWMON: Okay. Good. So we are  
25 talking about a reducing of air environment here.

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1                   CHAIRMAN WYMER: No, we are not, and the  
2 temperature changes by themselves are by the pumping  
3 action, and let alone the fact that the thing is  
4 permeable, and the water brings oxygen in with it, or  
5 some, and no nearly as much as the air.

6                   And in addition, once you get into the  
7 transport mode, then you are not necessarily in an  
8 oxidizing condition anymore -- and I will digress from  
9 our topic for a minute here.

10                  But as you go through the invert and  
11 through the material beneath the waste package, and  
12 down into the earth, you can there maintain a reducing  
13 environment I think quite a ways.

14                  DR. STEINDLER: No, I don't think so.

15                  CHAIRMAN WYMER: I do.

16                  DR. STEINDLER: You are going to get  
17 breathing of permeable rock, independent of whether it  
18 is above or below the drip. It is still unsaturated  
19 or in the unsaturated zone.

20                  DR. CLARKE: Probably 300 meters to that.

21                  DR. CAMPBELL: The general consensus is  
22 that this is a thoroughly oxidized environment because  
23 of this permeability.

24                  CHAIRMAN WYMER: But there is a  
25 recognition that there can be local reducing regions.

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1 DR. CAMPBELL: I would say the greatest  
2 chance of that is inside your waste package, where you  
3 have particularly small pin holes, cracks, and  
4 initially small patches, and a large mass of material  
5 that could act as a reducing agent inside the waste  
6 package.

7 DR. STEINDLER: Well, I will make some  
8 comments about what happens if you are fishing UO2,  
9 and you dump out two oxygens into the system per  
10 uranium, and now let's do a little arithmetic.

11 CHAIRMAN WYMER: And if you make fishing  
12 products which have an oxygen demand.

13 DR. STEINDLER: Well, that's what I am  
14 saying. If you then add up all the oxygen demands  
15 according to just their free energy formation.

16 CHAIRMAN WYMER: It is reducing.

17 DR. STEINDLER: That's right. Half the  
18 oxygen immediately goes to a whole raft of fairly high  
19 yield fishing products, whose oxidizer is more stable  
20 than UO2.

21 CHAIRMAN WYMER: That's right. And that  
22 is in fact true.

23 DR. STEINDLER: And then you can work your  
24 way down.

25 CHAIRMAN WYMER: And that is in fact true.

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1 You don't have enough oxygen to meet the demand of the  
2 fishing products.

3 DR. STEINDLER: And you also have a five  
4 component metallic alloy, which I think they call  
5 Epsilon Phase, but I am not sure that is quite right.

6 DR. SHEWMON: What do you mean? You don't  
7 like the use of Epsilon for that, or Epsilon means  
8 something else to you?

9 DR. STEINDLER: I thought that Epsilon  
10 meant something else, but it depends on whose Epsilon  
11 it is or whatever. So, yes, I think there is a  
12 reducing system.

13 DR. CAMPBELL: So I think the bottom line  
14 here is that within the drip itself there is always  
15 going to be a tendency, even with reducing agents  
16 available, and materials available inside the drip,  
17 there is always going to be a strong drive towards an  
18 oxidizing environment.

19 The waste package, until it is essentially  
20 open to the air or the drip, it is going to be --  
21 there could be a significant amount of reducing  
22 conditions.

23 CHAIRMAN WYMER: And we are concerned  
24 about the local conditions, and that's where the  
25 chemical corrosion is taking place. It is locally.

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1 Well, what happens globally is not such much the  
2 point. It is what happens specifically locally.

3 And if you have a global oxide  
4 environment, but a local reducing environment, then  
5 you are going to have a different corrosion regime.

6 DR. CAMPBELL: What about the effect of  
7 fluorides on titanium? Is there enough fluoride in  
8 the water to -- and especially in concentrated water  
9 to be an issue here?

10 DR. SHEWMON: Didn't I say that fluorides  
11 are worse here someplace?

12 CHAIRMAN WYMER: They are almost always  
13 worse.

14 DR. SHEWMON: I don't know what kind of a  
15 scenario -- what do you have to do to get very  
16 concentrated fluoride solutions?

17 DR. CAMPBELL: Well, the water itself has  
18 fluorides in it.

19 DR. SHEWMON: Yes, the 10 to the minus 5  
20 levels, and 10 to the minus 6.

21 CHAIRMAN WYMER: Let's minimize the side  
22 discussions and hear from Gustavo.

23 DR. CRAGNOLINO: Yes, completing what was  
24 already mentioned, and the issue that you want to  
25 address on spent fuel, but not for waste package, and

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1 neither for the drip shield. This was our analysis  
2 and we don't pay attention to the issue --

3 CHAIRMAN WYMER: And for a very good  
4 reason, because if the waste package has already  
5 failed, why pay any attention to it.

6 DR. CRAGNOLINO: This is the issue.

7 CHAIRMAN WYMER: So that's right. Okay.  
8 Well, this might be a good -- any other observations  
9 or sage remarks here?

10 DR. CAMPBELL: Sage remarks?

11 CHAIRMAN WYMER: That's kind of a spice  
12 that you put on things. Maybe this is a good time to  
13 hear from you, Gustavo.

14 DR. CRAGNOLINO: Well, this is only a  
15 brief remark regarding the comment that Paul Shewmon  
16 made about the possibility of having a good natural  
17 analog for Alloy 22.

18 And the issue that we confronted on one  
19 side was the fact that the stability, the long term  
20 stability is not based by any means on long term  
21 considerations.

22 It is based on direct finds, because a  
23 passive film is not an established structure that  
24 remains there. It is a completely dynamic type of  
25 structure, and it is strictly related or correlated

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1 with the behavior of the environment.

2 CHAIRMAN WYMER: The problem that I have  
3 with -- well, I will defer that.

4 DR. SHEWMON: I would like to ask one  
5 question. These meteorites have been taken out of  
6 places like Iowa and Kansas, too. You would say that  
7 that is wet, and it has been wet for millions and  
8 millions of years, and you are saying that it hasn't  
9 got oxygen, and that's why it has survived?

10 DR. CRAGNOLINO: (Off mike.)

11 DR. SHEWMON: But why do the meteorites  
12 stay there then?

13 DR. CRAGNOLINO: Well, I think that is  
14 because as Mr. Wymer stated, because of a particular  
15 condition in the climate, in the weather, and not only  
16 humidity.

17 DR. SHEWMON: Well, over a hundred-million  
18 years, you get a fair number of cycles.

19 DR. CRAGNOLINO: Right. But I think we  
20 can discuss this with more information.

21 DR. AHN: I would like to add Gustavo has  
22 stated, and more housekeeping information for you. In  
23 the waste form performance studies, actually they  
24 analyzed Penna Blanca (phonetic) uranium deposits and  
25 compared with the laboratory testing over spent

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1 nuclear fuel.

2 And in the lab testing, they identified a  
3 sequence of passive fuel information the beginning,  
4 and they eventually ended up with their own acidity.

5 They observed the exact sequence in the  
6 Penna Blanca type over a million years.

7 DR. SHEWMON: What site was this?

8 DR. AHN: Penna Blanca. That gives us  
9 very good insight and perhaps we need to reduce the  
10 uncertainty of what the establishment is saying, and  
11 on the other hand, we also look at patterns and  
12 verification or validation.

13 DR. SHEWMON: What happened? Was this a  
14 meteorite site or what happened at Penna Blanca?

15 DR. CAMPBELL: It is a uranium body that  
16 has been studied as a natural analog for Yucca  
17 Mountain.

18 DR. AHN: Perhaps we could get better  
19 insight from the analysis -- regarding the stability  
20 of -- in C-22, another view that we considered.

21 CHAIRMAN WYMER: One of the things that I  
22 have a question, or a problem, or misgivings about is  
23 the relationship of polarization studies, which do  
24 tell you a lot about under what conditions and whether  
25 or not something is going to corrode on the one hand,

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1 and what they mean with respect to the actual  
2 understanding of the mechanism of corrosion on the  
3 other hand.

4 We seem to have somehow substituted  
5 polarization studies for mechanism studies, or we have  
6 used polarization studies instead of going after and  
7 understanding the mechanisms. Am I off-base on that?

8 DR. SHEWMON: No, that's right, and that  
9 has no build-up of ions, and none of that sort of  
10 stuff that traditionally stops or slows our actions  
11 down.

12 CHAIRMAN WYMER: Elaborate on that a  
13 little bit.

14 DR. SHEWMON: Well, if you put out a very  
15 high voltage to it, you can get what they get  
16 polarization.

17 CHAIRMAN WYMER: Right.

18 DR. SHEWMON: Which means that it slows  
19 down. But with these very slow tests that they do,  
20 they do vary the oxidize potential, and that they have  
21 moving solutions carry the ions away. And I guess  
22 there is not a preferential solution and we could get  
23 into that.

24 DR. STEINDLER: Well, let me just make a  
25 comment. You are looking at either gas solid or

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1 liquid solid reactions. The solid tends to be an  
2 unstable alloy of some sort.

3 CHAIRMAN WYMER: It certainly is.

4 DR. STEINDLER: And whose composition is  
5 fairly well defined, but whose chemical activities of  
6 the components are not chemically or very well  
7 defined.

8 So to ask can we get at the mechanism of  
9 this heterogeneous reaction in an unstable system, et  
10 cetera, et cetera, my comment is that I bet you can,  
11 but not if you want to put a repository together in 10  
12 years.

13 CHAIRMAN WYMER: I agree with that.

14 DR. STEINDLER: So that, and that general  
15 system is also true in waste form corrosion.

16 CHAIRMAN WYMER: I know how hard it is to  
17 get true mechanisms.

18 DR. STEINDLER: I am trying to get you  
19 away from science, Ray. We have got a mountain to  
20 fill up.

21 CHAIRMAN WYMER: Well, I am not opposed to  
22 polarization studies. I think that they do give you  
23 a lot of insight into the stability of a system,  
24 provided that they are done under the right  
25 conditions, and with the right temperatures, and --

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1 DR. STEINDLER: I don't mean to cast  
2 dispersions on the need for studies of that kind, but  
3 mechanism studies are very difficult to do.

4 CHAIRMAN WYMER: And I would point out  
5 that the NWTRB also says that you need to know  
6 something more about mechanisms. Now, it doesn't mean  
7 that you have to fully understand the mechanisms, but  
8 a little more insight would certainly be helpful.

9 DR. CAMPBELL: Let me add something here  
10 about soil processes, Paul, that may have an impact on  
11 the longevity or not of a meteorite fragment. And one  
12 of the things that occurs in soils is that you get a  
13 tendency towards a reducing environment, particularly  
14 if the soils tend to be saturated, and you have a fair  
15 amount of organic matter there.

16 As you go down into the soil profile, you  
17 can get a fairly oxygen depleted environment. In  
18 fact, you can get reducing conditions that can lead to  
19 even like methane forming.

20 So the longevity of these things in a  
21 wetter soil environment can very well be affected by  
22 the removal of oxygen by natural processes, by  
23 bacterial processes in the soils.

24 And there is a fair bit of difference  
25 between that environment and Yucca Mountain, where you

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1 have a large void space, with interconnected fractures  
2 that are permeatable, and you get barometric pumping,  
3 and you can get oxygen flowing into and through that  
4 system.

5 And albeit at a slower rate than you would  
6 in open air, but you still have a fair bit of  
7 permeability there that you may very well have a  
8 saturated environment, where these things in Kansas  
9 and Nebraska are found.

10 DR. SHEWMON: So we get back to meteor  
11 crater, which is probably as porous as Yucca Mountain,  
12 and that is only a hundred-thousand years old, and so  
13 that fits in with your model.

14 DR. CAMPBELL: Well, it is a dryer soil  
15 environment, and maybe Gustavo -- it looks like he has  
16 a point that he wants to make on this.

17 DR. CRAGNOLINO: I think I would make a  
18 point the following way. Let's assume that this type  
19 of meteorite is in the right environment, but you  
20 don't know if there are meteorites in other types of  
21 environment. I am going to make the point that to  
22 sustain in some way this point of view that there are  
23 artifacts that have been under relatively reducing  
24 conditions, probably oxidizing at one point in time,  
25 but later on reduced, that were able to absorb

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1 selectively in the oxidizing side layer chloride.

2 This is the type of oxide hydroxide for --  
3 and they have like a -- and if you keep this in a dry  
4 place, this artifact looks splendid, and covered by  
5 some sort of -- and as soon as you get certain layers  
6 of humidity, they almost explode because they are full  
7 of fluoride, and the oxide cannot preserve it.

8 We cannot negate the possibility that  
9 artifacts, like the type that you mentioned, like  
10 meteorites, will not be able to sustain conditions in  
11 certain types of environment while in another one, and  
12 this is what corrosion is all about.

13 DR. SHEWMON: And they will be born with  
14 very dense oxide on the surface, because they came in  
15 under very high temperature conditions, and I don't  
16 know whether that has anything to do with the  
17 stability.

18 CHAIRMAN WYMER: Of course, the only ones  
19 we have found are the ones that are in living  
20 conditions where they can survive.

21 DR. SHEWMON: That's true.

22 DR. STEINDLER: Apparently both the staff,  
23 as well as DOE, use a statistical approach for the  
24 corrosion of the surface. How good is that?

25 CHAIRMAN WYMER: And by that, explain what

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1 you mean by statistical.

2 DR. STEINDLER: Well, they divide the surf  
3 ace into patches, and the patches don't all corrode at  
4 once, and that is the drip shield, and I can go down  
5 another layer, and there are patches in the waste  
6 package, and they don't all corrode at once.

7 CHAIRMAN WYMER: And then of course you  
8 say that when there are enough patches that are big  
9 enough that they can release enough stuff that it  
10 matters, then you have got a problem.

11 DR. STEINDLER: Well, that's what I am  
12 driving at, exactly. Does that make sense?

13 DR. SHEWMON: It makes more sense for the  
14 drip shield than it does for the package to me,  
15 because the drip shield is going to have different  
16 things dropping on it, and you will have a very  
17 heterogeneous surface.

18 And whether it has to do with the odd  
19 steel bowl, or rocks, or whether there is some paste  
20 that came out of the cement that dripped down on it,  
21 as long as you have got this integral shield over the  
22 top, it seems to me that it is a lot harder to see if  
23 the -- the metal is quite homogeneous.

24 Gustavo says they don't see crevice or  
25 localized pitting corrosion problems. So with regard

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1 to the build-in, the inherent inhomagey (phonetic)  
2 beyond the metal would be rather low.

3 But up on this roof there is all manner of stuff.

4 DR. STEINDLER: All right. So the  
5 statistics on the top are fine, and I am trying to  
6 chase this down to see whether or not the model that  
7 I sense -- and, boy, if you ask me to explain it in  
8 detail, I am in trouble.

9 But the model that DOE and the staff seem  
10 to be accepting is that you will get penetration of  
11 the drip shield in places. You will get penetration  
12 of the outer barrier, and the stainless steel  
13 underneath it in places.

14 And you will begin to attack the circular  
15 cladding in places, and now things really get unglued  
16 as far as I can tell. As soon as you get down below  
17 that, all of a sudden the whole system is infinitely  
18 quickly mixed. And evolution out of that now is --

19 CHAIRMAN WYMER: Not only that, but the  
20 stuff that hits the new material has in it the  
21 ingredients of everything it corroded in getting down  
22 there.

23 DR. STEINDLER: Yes, but I am just trying  
24 to get up above that, and you made the comment about  
25 statistics.

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1 DR. SHEWMON: I don't where they get their  
2 randomizing factor, and what they take it for. But I  
3 guess I just --

4 DR. STEINDLER: You think it is a sensible  
5 approach.

6 DR. SHEWMON: On the top it is, but  
7 underneath it, it is hard to see.

8 CHAIRMAN WYMER: Well, again, to digress  
9 rather wildly, if you wanted to challenge anything,  
10 you would challenge the 10,000 year period, because  
11 this stuff doesn't really start to happen for a  
12 hundred-thousand years.

13 DR. STEINDLER: Well, that's challenging  
14 in the wrong direction.

15 CHAIRMAN WYMER: I know that.

16 DR. STEINDLER: If you were an intervenor,  
17 that's not where you would --

18 CHAIRMAN WYMER: I realize that I said  
19 that.

20 DR. STEINDLER: But my question to what  
21 your earlier comments were as to what you think our  
22 function is, is to address the question of does that  
23 make sense, and it sounds that up to a point it makes  
24 sense.

25 CHAIRMAN WYMER: Up to a point.

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1 DR. STEINDLER: It gets a little iffy I  
2 think further into the fuel you go.

3 CHAIRMAN WYMER: I think we can make a lot  
4 of observations. I think we have to be extremely  
5 careful about the conclusions that we draw with  
6 respect to what it means in repositories.

7 DR. STEINDLER: I don't draw any  
8 conclusions. That's your role.

9 CHAIRMAN WYMER: Well, that's all of our  
10 roles, and the conclusions will not be nearly as  
11 radical as our observations I would think.

12 DR. CAMPBELL: I think Tae Ahn may have a  
13 clarifying point.

14 DR. AHN: Yes. I would like to provide  
15 you with additional information. In our evaluation of  
16 the early program, we have chosen a risk informed  
17 approach, which means that in environmental conditions  
18 that are concerned, for instance, we have randomly  
19 chosen the barometer conditions.

20 We don't accept a hundred percent of a  
21 highly acidic containing environment. In other words,  
22 there is a distribution of the chemistry, and so I  
23 would like you to consider that factor.

24 Also, in terms of regarding the  
25 statistical analysis, again we have distributions, and

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1 it is a risk informed approach, and it is not just the  
2 single permissive value of years.

3 DR. SHEWMON: So this means that the Ph  
4 and fluoride concentrations are different for these  
5 little squares when the rate of corrosion in this  
6 square is calculated? It doesn't have to be physical  
7 in the sense that I was thinking of.

8 CHAIRMAN WYMER: Well, the whole concept  
9 of risk informed is that it gets back to the business  
10 of conservatism and credibility, and believability.

11 How risk informed are you if you really  
12 don't understand the processes that make up the risk.  
13 Just how informed are you, and in a sense you are risk  
14 informed. But not as risk informed as you would like  
15 to be.

16 DR. STEINDLER: No, I understand. That's  
17 not a problem.

18 CHAIRMAN WYMER: We do have 15 minutes  
19 left, and so let's break from what I said earlier, and  
20 field any questions from the group.

21 AUDIENCE: Just a point of clarification.  
22 There seems to be some concern about when the drip  
23 shield fails and what it means. As far as the  
24 corrosion of the waste package is concerned, we are  
25 assuming the same environment on the waste package

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1 with or without the drip shield.

2 The basis for that is that there is going  
3 to be a lot dust and stuff like that on the panel  
4 environment before the drip shield is raised, and they  
5 may contain hygroscopic material.

6 And so when the humidity goes up, you are  
7 likely to find as much across film on it that produces  
8 humidity or whatever. So we are assuming the same  
9 environment, and so the corrosion starts as soon as  
10 the humidity threshold gets in.

11 CHAIRMAN WYMER: Well, that assumption  
12 cannot be strictly true, of course, but it may be true  
13 as to an approximation and that's okay. It can't be  
14 true because in fact the composition of the water has  
15 been changed by the process of corroding the drip  
16 shield.

17 AUDIENCE: That's true, but what I am  
18 saying is that it doesn't have to -- the water doesn't  
19 have to come through the drip shield, because there is  
20 an open environment between the drip shield and the  
21 waste package.

22 So when the humidity gets up to 50 percent  
23 --

24 CHAIRMAN WYMER: Only the water is  
25 transported.

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1 AUDIENCE: Right. But then there is --

2 DR. SHEWMON: It came in by the gas phase  
3 and not the --

4 AUDIENCE: Right.

5 CHAIRMAN WYMER: Most of the dust in our  
6 observations collects on the tops of things and not  
7 under them.

8 AUDIENCE: Well, the drip shield doesn't  
9 replace until the water closure, and the waste package  
10 has been sitting there for quite some time, and that  
11 is an assumption in our model anyway. So I just  
12 wanted to clarify that.

13 CHAIRMAN WYMER: So you are saying there  
14 may be 300 years worth of dust?

15 AUDIENCE: Yes, exactly.

16 CHAIRMAN WYMER: That's a good point.

17 AUDIENCE: So all I was getting at was  
18 that for the waste package to start corroding, it  
19 doesn't have to wait for the drip shield to corrode.

20 CHAIRMAN WYMER: My original feeling about  
21 airborne dust was that it didn't amount to much, but  
22 the more I thought about it, the more I thought that,  
23 gee, it does.

24 AUDIENCE: Well, there is going to be  
25 ventilation going on, and I don't think the

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1 ventilation have got filters in it.

2 DR. CRAGNOLINO: You may consider in the  
3 future electronic components.

4 CHAIRMAN WYMER: Right. That's why they  
5 have cleaners.

6 DR. STEINDLER: And that raises the  
7 question that I would have for Paul. Vapor phase  
8 corrosion is one thing and liquid corrosion is  
9 another. Would you equate the two, which is what I  
10 think they seem to be doing, in terms of rates?

11 DR. SHEWMON: Well, no, if vapor stays  
12 vapor, that you have got this magical monolayer or  
13 whatever that has all the properties of a flowing  
14 electrolyte, or even a stationary electrolyte.

15 DR. STEINDLER: I see. Okay.

16 DR. SHEWMON: You still have the problem  
17 of waste buildup that isn't treated very well with  
18 these cell approximations, but you still can bring  
19 water in.

20 DR. STEINDLER: If the mechanism were like  
21 glass, then you would be in trouble, because you can't  
22 pile up enough silicate in glass to slow the reaction  
23 down.

24 DR. CAMPBELL: One of the things that  
25 certainly I have noticed over the years in various

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1 tours through Yucca Mountain is that you pass by these  
2 placards and other things that when they are first put  
3 through the DSF were nice and clean, and over time  
4 those things have been heavily coated with dust.

5 And that is a process that is going to  
6 occur when they are drilling these drips and --

7 DR. SHEWMON: What we need is a monsoon  
8 every so often that will wash it all off.

9 DR. CAMPBELL: Wash it all out, right.  
10 But over the operation period of the repository, you  
11 definitely are going to have a significant build up of  
12 stuff on the surfaces.

13 CHAIRMAN WYMER: Yes, I certainly after  
14 reflection arrived at that position, too.

15 DR. STEINDLER: But, folks, that is a  
16 different kind of material than something that has  
17 been formed by evaporation of a soluble salt.

18 CHAIRMAN WYMER: Absolutely. It is a  
19 solitious material for the most part.

20 DR. STEINDLER: So you kind of have to ask  
21 the question what is this dust really going to  
22 contribute on my magic two monolayer thick film on the  
23 waste package or whatever.

24 CHAIRMAN WYMER: And to what extent will  
25 it be washed off before anything happens. These are

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1 all subtleties that have not been dealt with and are  
2 almost impossible to deal with, and probably are not  
3 important, although we don't know.

4 DR. STEINDLER: I suppose --

5 DR. SHEWMON: It is not the J-13 water  
6 that comes in.

7 CHAIRMAN WYMER: It is not J-13 water for  
8 sure.

9 DR. SHEWMON: It is pure water.

10 DR. CAMPBELL: And the layer of water on  
11 this surface is not going to be J-13 water either.

12 CHAIRMAN WYMER: That's right.

13 DR. CAMPBELL: It is going to be some sort  
14 of evaporative water.

15 DR. STEINDLER: It will be in equilibrium  
16 with the atmosphere, and so it will have carbonate in  
17 it.

18 CHAIRMAN WYMER: That is about the one  
19 thing that it can have, yes. The Phs spike up pretty  
20 good temporarily, but they do not, however, ever spike  
21 down in any of the models that we have seen.

22 DR. SHEWMON: That's interesting.

23 CHAIRMAN WYMER: And that is an  
24 interesting thing.

25 DR. SHEWMON: Most of these cell

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1 approximations are in acids.

2 CHAIRMAN WYMER: Well, the one thing about  
3 nitrous acid, of course, is that it is much more  
4 active as a dissolving re-agent. It is more active  
5 than nitrate acid, and it doesn't have the driving  
6 force, but it has the kinetics that are in general  
7 faster.

8 DR. SHEWMON: A minute ago we were saying  
9 that the CO2 in the air would tend to drive the Ph up,  
10 and then we have the nitric acid --

11 CHAIRMAN WYMER: And the cement.

12 DR. SHEWMON: And then how did we get it  
13 lower?

14 CHAIRMAN WYMER: Radiocist of nitrogen  
15 in the air and actual oxygen, or peroxide radicals to  
16 form nitric acid. Wasn't that your statement?

17 DR. SHEWMON: That is the only thing that  
18 could spike it, yes.

19 DR. AHN: On the surface of the waste  
20 package, we can include all tests on severe  
21 environment. However, as I mentioned here, in the  
22 risk assessment, those in the distribution, the actual  
23 impact on the performance could be a small fraction  
24 rather than failure, and we need to review the basis  
25 for doing that, and --

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1                   CHAIRMAN WYMER:        About the only  
2 fundamental objections that I can make as to what has  
3 been done is that it doesn't satisfy me  
4 scientifically. But I think the bounding conditions  
5 and the other assumptions that are made are  
6 reasonable, and they cover --

7                   DR. AHN: And that is the kinds of things  
8 that we are reviewing.

9                   CHAIRMAN WYMER: And it just doesn't  
10 satisfy me that you really don't understand the  
11 mineral, but still it is probably adequate for NRC's  
12 purposes. It is a strange position to be put in for  
13 a scientific area.

14                  DR. LESLIE: Since Andy opened it up, this  
15 is Bret Leslie from the NRC staff, and I guess I made  
16 some notes as Ray started off the meeting this morning  
17 on what this working group is trying to get at, which  
18 is to come up with some further consensus on whether  
19 the NRC process to resolve the issues is appropriate.

20                  And I guess one of the things that comes  
21 to my mind is that this has been a great scientific  
22 discussion, but where has the evaluation of the  
23 agreements that the NRC staff done?

24                  CHAIRMAN WYMER: That will come, I hope,  
25 tomorrow morning.

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1 DR. LESLIE: Okay. Because it looks like  
2 there are several different discussions as you go  
3 along and I am not hearing anything that is saying how  
4 is this resolution process good or bad, and I am just  
5 wondering when that is going to happen.

6 DR. STEINDLER: But you may have heard  
7 some comments about the staff didn't seem to raise a  
8 particular point, and that in itself I think is  
9 important.

10 CHAIRMAN WYMER: And that is what we are  
11 digging at now.

12 DR. STEINDLER: If the staff accepts DOE  
13 without any particular comment as you heard in the  
14 conservatism issue, then that represents a question  
15 that needs to be raised; why did they do that and  
16 should they have done that is an issue that the  
17 committee ultimately -- the ACNW ultimately will have  
18 to decide, either to put in a message to the  
19 Commissioners or not.

20 CHAIRMAN WYMER: I wanted to detail  
21 chemical discussions in order to get everybody sort of  
22 in the same ball park, and then we are going to back  
23 off and say what does it mean, and is the process  
24 getting NRC to where it needs to be to make the site  
25 suitability, or contribute to that recommendation, and

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1 to the license application.

2 But first I really wanted to dig into all  
3 these chemistry issues and just see if we brought up  
4 a snake to use an old southern expression.

5 It is very unlikely that we are going to  
6 get any pythons, but we might get a few small snakes.  
7 That's the way that the process is working here, Bret.

8 Tomorrow we need to actually address how  
9 is the process working, and is it working, and how  
10 independent of DOE's positions is the process, and how  
11 much, if at all, are you being swept along by the DOE  
12 tide, and there is a massive effort under way, and a  
13 lot of money being spent, and are we being submerged,  
14 or are we keeping our heads above water here.

15 DR. STEINDLER: I assume tomorrow morning  
16 you are going to start at six o'clock?

17 CHAIRMAN WYMER: No earlier than that.  
18 Absolutely. I think we ought to break for lunch. We  
19 are due back at one o'clock.

20 (Whereupon, a luncheon recess was taken at  
21 11:30 a.m.)

22

23

24

25

## A-F-T-E-R-N-O-O-N S-E-S-S-I-O-N

(1:00 p.m.)

CHAIRMAN WYMER: All right. The first topic here after lunch is the overview of the Near-Field Chemistry issues and TSPA-SR Source-Term Model, by Andy Campbell.

DR. CAMPBELL: Okay. And I am going to basically do what I did earlier this morning, is we will come back to this view graph from the DOE and the FDA, which shows the key areas of concern, in terms of the drip.

Basically what I asked Marty to do was to look at the chemistry inside the waste package, and then I believe we were also going to talk a little bit about how that mobilization, potential mobilization of radionuclide extend and exit through the invert.

So that is basically the portion of the system that we are looking at now at this point. In terms of the flow diagram that we are looking at, the in-waste package chemistry and corrosion, and cladding, the degradation of the spent fuel, and the transport of -- the potential transport of radionuclides basically through the invert.

DOE, you will see, doesn't really have a release model, per se. What they basically assume is

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1 whatever water gets into the waste package, an equal  
2 amount of water gets out of the waste package.

3 So they don't have a particular mechanism  
4 or model for the contaminated water escaping from the  
5 waste package. I am going to have to move this up and  
6 down.

7 One of the degradation mechanisms that  
8 they are looking at is the corrosion of the cladding,  
9 and the interaction of just that fuel with water, the  
10 way the deal with that is not entirely obvious here.

11 But the fact that the waste package ports  
12 are filled with glue, the assumption is made that the  
13 entire waste package void space is filled with water,  
14 and that is about 4-1/2 cubic meters of water.

15 It is an operating assumption that they  
16 use in order to do the calculations. So even if --  
17 and the input of water into the top of the waste  
18 package is somewhere based upon their infiltration  
19 models between about 1-1/2 liters per year to up to  
20 150 liters per year.

21 And that is based upon different  
22 percolation rates, and how much water is diverted and  
23 so on. The assumption is that if water is dripping on  
24 top of the waste package that it goes into the waste  
25 package.

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1 I can't find an easy explanation, and in  
2 the NRC's TPA model there is some diversion factor  
3 that I talked about earlier for water to essentially  
4 roll off the side of the waste package, as opposed to  
5 going in, but it doesn't appear to be a DOE model.

6 So they have anywhere between 1-1/2 and  
7 150 liters, and in TSPA that is abstracted into three  
8 in-fluxes of water; 1-1/2, 15, and 150 liters per  
9 year.

10 And so then the water that comes out of  
11 the waste package is an equivalent volume to the  
12 incoming water. But, of course, that is now water  
13 that is equilibrated with spent fuel, and the  
14 materials inside the waste package, and that is all  
15 done with this EQ36 reaction path code.

16 DR. STEINDLER: Well, I think that it is  
17 important that their code, I believe, assumes  
18 instantaneous mixing of that 4-1/2 cubic meters with  
19 whatever --

20 DR. CAMPBELL: This is a classic stirred  
21 bath model. There is no nooks and crannies where you  
22 get different chemistry than you do in the entire  
23 bath. It is basically 4,500 liters of water that  
24 starts out life with a composition similar to J-13.

25 And a bunch of materials that are going to

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1 be inside the waste package, including certain  
2 fractions of spent fuel available for interaction with  
3 that water.

4 CHAIRMAN WYMER: Which is certainly a bad  
5 assumption, because in order to have gotten through  
6 the steel container, and in order to have gotten  
7 inside rather I should say, it will have to have  
8 dissolved some stuff to get in there, and that will --  
9 the ingredients or whatever that is dissolved will be  
10 present in the water.

11 DR. STEINDLER: But it only dissolves on  
12 the top.

13 CHAIRMAN WYMER: How much difference this  
14 will make you don't know, and I think that is the  
15 point, that you don't know.

16 DR. STEINDLER: Well, I guess the thing  
17 that concerned was that you have this large amount of  
18 inventory, static inventory, which is diluted by in  
19 the lowest case 1-1/2 liters in a year, and that has  
20 undergone a small amount of reaction, relatively small  
21 reaction, with the spent fuel, which is instantly  
22 diluted by this 4-1/2 cubic meters.

23 And out of that soup now comes at some  
24 time in the future, secondary mineral formation,  
25 colloids and so forth, and so on, and it can make a

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1 hell of a difference if that 4-1/2 cubic meters  
2 weren't there.

3 DR. SHEWMON: Does it run out the bottom,  
4 or does it have to diffuse out the top?

5 DR. CAMPBELL: Their model does not  
6 account for it. It just magically goes from inside  
7 the waste package to the top of the material -- at the  
8 bottom, or underneath the waste package, and it is  
9 just --

10 DR. SHEWMON: Well, you know, both of  
11 these assumptions are wrong, but how many orders of  
12 magnitude would it change things? Did they do  
13 anything to try and do that?

14 DR. CAMPBELL: At this point, they are  
15 committed to looking at evaporative processes, but it  
16 is not clear at all to me that they are going to look  
17 at evaporative processes that minimize the amount of  
18 water in the waste package.

19 They are just assuming that if we drill  
20 holes in the top of it that we are going to drill  
21 holes in the bottom of it, and that whatever gets in,  
22 gets out.

23 Now, I will give you an idea. The NRC  
24 also has a bath model, but it is a spill-over model,  
25 and the location of the whole in the side that spills

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1 out is a sample perimeter. So it randomly samples  
2 between the bottom and the top of the waste package.

3 So a certain fraction of waste packages on  
4 average are about half-filled, just because of the way  
5 that they do the sampling. And then it assumes that  
6 there is a hole in the side, or up here, or down here,  
7 that allows water out.

8 And then only the fuel, if I understand it  
9 correctly, in the NRC model, only the fuel that would  
10 be emersed in water could react with that water, or  
11 some fraction of it.

12 DR. SHEWMON: For example, this gives the  
13 zercoroy (phonetic) zero life around the fuel?

14 DR. CAMPBELL: No, in both the -- I  
15 believe in the DOE model and in the NRC model, there  
16 is some credit given to the zercoroy for cladding.  
17 The way that is implemented in TSPA -- and I think in  
18 TPA -- is that a fraction of the cladding of the fuel  
19 is available to interact with the water, but not all  
20 of it. Is that correct?

21 DR. AHN: Yes. Credit was given to  
22 cladding by DOE and not by NRC.

23 DR. CAMPBELL: Okay. So in the TPA code  
24 there is no cladding added.

25 DR. CODELL: It is in there.

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1 DR. AHN: Yes, it is in there.

2 DR. CAMPBELL: That's what I thought.

3 DR. AHN: But not in this case.

4 DR. CAMPBELL: The NRC has a series of  
5 alternative models that they have explored in their  
6 own code which evaluate things like if you take credit  
7 for cladding, and how will that affect your results.  
8 And maybe you might address that at some point.

9 DR. STEINDLER: Now, cladding credited by  
10 DOE is a relatively recent change, right?

11 CHAIRMAN WYMER: Yes, that's my  
12 understanding.

13 DR. STEINDLER: And that is the picture  
14 that I have.

15 DR. CAMPBELL: But the way that they  
16 present it is that they have some fraction of the fuel  
17 is available to interact with water, and that is how  
18 they implement the cladding credit. They do  
19 calculations on the side to determine how much  
20 cladding has failed, and how much has not failed.

21 DR. STEINDLER: And that fraction is a  
22 function of time?

23 DR. CAMPBELL: Yes. And so not all the  
24 fuel within the rods are available to interact with  
25 the water. But what is available is assumed to reach

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1 equilibrium with the entire 4-1/2 cubic meters of  
2 water inside the waste package.

3 CHAIRMAN WYMER: Or it reached a steady  
4 state at any rate, and presumably the water is  
5 continually changing with time as well.

6 DR. CAMPBELL: The volume of input water  
7 relative to the volume of the stirred bath --

8 CHAIRMAN WYMER: Is very small.

9 DR. CAMPBELL: -- is relatively small. So  
10 the impacts on the chemistry of the input water is  
11 relatively small. So from a purely calculational  
12 view, you can see why this became an attractive model  
13 to work with.

14 The concern that I have -- and this is my  
15 own concern -- is that the water that gets into this  
16 system and that can interact with this fuel, is not J-  
17 13 water.

18 It is some water that has undergone -- it  
19 may have started out life somewhere in the ball park  
20 of J-13, but it has gone through an evaporative  
21 process, because even until you are several tens of  
22 thousands of years down the road, the fuel is the  
23 hottest thing in the repository.

24 CHAIRMAN WYMER: Well, it has got a lot of  
25 iron in it, too.

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1 DR. CAMPBELL: So there is an evaporative  
2 process that is not accounted for, and so the  
3 chemistry of this water is going to be more  
4 concentrated than something like J-13, which is a  
5 fairly --

6 CHAIRMAN WYMER: The chances are of  
7 reducing the water as well, since it will have gotten  
8 in there by corroding the steel container.

9 DR. CAMPBELL: Well, presumably whatever  
10 caused the corrosion to the container has left a hole  
11 in it, and you can get water into that hole from the  
12 outside system.

13 But again you have got this large volume,  
14 4-1/2 cubic meters of essentially buffer volume of  
15 water in the system.

16 DR. STEINDLER: But the turnover in the  
17 lowest flux case is 3,000 years. Your pictures came  
18 out better than mine. I couldn't even read the print.

19 CHAIRMAN WYMER: What is your point,  
20 Marty?

21 DR. STEINDLER: Well, at a liter-and-a-  
22 half per year influx rate, with a 4,500 liter  
23 inventory, your turnover is something in the  
24 neighborhood of 3,000 years. It gets to be 300,000  
25 years for the highest flux.

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1           It isn't very clear to me what that  
2 assumption does for them. You know, that you have got  
3 something other than essentially an empty container.  
4 But it does confuse the chemistry.

5           CHAIRMAN WYMER: It certainly confuses the  
6 chemistry. I think it does allow them to calculate  
7 it.

8           DR. STEINDLER: Well -- okay. How much  
9 faith have you got in that EQ36 code?

10          CHAIRMAN WYMER: Well, you know, garbage  
11 in and garbage out. Good data in and good data out.  
12 It is the same old story.

13          DR. CAMPBELL: I will say that all of the  
14 thermodynamic modeling codes have limitations. In  
15 terms of applications, EQ36 is probably as good as  
16 any. There maybe some that are better, and some that  
17 are worse, but the key issue is the database that you  
18 work with.

19          CHAIRMAN WYMER: That's exactly right.

20          DR. CAMPBELL: The mechanism and the  
21 processes incorporated into those codes are all not  
22 that different from one equal thermo code to another.

23                 How you make up for limited data, the  
24 biggest problem that I see with all these codes is  
25 that they tend not to deal with co-precipitates. They

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1 tend not to deal with salt solutions and things like  
2 that, which are the real world.

3 CHAIRMAN WYMER: They tend not to put  
4 everything in the water that is in the water.

5 DR. CAMPBELL: This is just showing what  
6 I have already talked about briefly, in terms of what  
7 the TSPA code is calculating, and there is a  $pCO_2$ , the  
8 partial pressure of carbon dioxide, and partial  
9 pressure of oxygen, and Eh, the redox state of the  
10 system, the ionics strength. And then the key species  
11 are fluoride, chloride, and carbonate.

12 CHAIRMAN WYMER: They just have two time  
13 regimes; one less than a thousand years and one  
14 greater than a thousand years?

15 DR. CAMPBELL: Basically, because remember  
16 that the key temperatures spike when you get a  
17 significant temperature increases and are in that less  
18 than a thousand year period.

19 CHAIRMAN WYMER: I was thinking that in  
20 this other thing we had a while ago that they had  
21 three temperature regimes.

22 DR. STEINDLER: Three time regimes.

23 CHAIRMAN WYMER: I'm sorry, yes, time  
24 regimes.

25 DR. CAMPBELL: Time regimes for the waste

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1 packages. This is the in-package.

2 CHAIRMAN WYMER: What does that say that?  
3 Does that say at temperature, or what does that say?  
4 I can read the thousand years, but --

5 DR. CAMPBELL: At failure.

6 CHAIRMAN WYMER: At failure? Okay. That  
7 is blurred to me.

8 DR. STEINDLER: But that fluoride is only  
9 true for glass. I don't think they do much  
10 calculations for it, for fluoride and UO<sub>2</sub>.

11 DR. CAMPBELL: Well, remember that they  
12 are also looking at high level glass degradation in  
13 the co-disposal containers.

14 DR. CRAGNOLINO: The fluoride is not  
15 incorporated in order to deal with the solution of the  
16 radiated uranium dioxide. It is used as a surrogate  
17 for cladding. They have a model for the dissolution  
18 of cladding, on the basis of cladding, and this is the  
19 reason that it is there.

20 But it is not incorporated in the  
21 barometric equation for the dissolution of the  
22 radiated fuel.

23 DR. STEINDLER: Well, I sure missed that.

24 CHAIRMAN WYMER: So did I.

25 DR. CAMPBELL: And based upon the model,

1 these are the calculated in-package Phs, and I am  
2 going to have to magnify again to see them. For the  
3 commercial spent nuclear fuel -- and by the way, if  
4 anybody is missing and needs extra copies, I can get  
5 more made in case we need them.

6 Again, the interesting thing about this,  
7 and that I found interesting, is the uncertainty based  
8 upon the TSPA calculation, the Ph is larger in the  
9 beginning than after the longer time frames.

10 That was just an observation. But these  
11 are the -- well, somewhere between 4 and 7 of the  
12 first thousand years.

13 DR. STEINDLER: Is there a message there?

14 DR. CAMPBELL: And between about 6 and a  
15 little above 7 --

16 CHAIRMAN WYMER: What sends it down to  
17 four?

18 DR. CAMPBELL: Particular combinations of  
19 corrosion, water flux, and other conditions.

20 CHAIRMAN WYMER: From the chromium?

21 DR. CRAGNOLINO: Yes, and what is in the  
22 in-package calculations would be between -- but all the  
23 things that is inside the waste package, materials  
24 that are together, are run and they come out with  
25 this.

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1 CHAIRMAN WYMER: Well, the reason that  
2 raises my interest is because you are getting down now  
3 to Ph ranges where you can with iron reduce plutonium,  
4 and to reduce the plutonium is a very significant  
5 thing, and it is a danger as far as transport is  
6 concerned.

7 DR. CAMPBELL: Ray, the time here is a  
8 thousand years.

9 CHAIRMAN WYMER: I see that.

10 DR. CAMPBELL: And you do have higher  
11 temperatures in this regime.

12 CHAIRMAN WYMER: And something has to fail  
13 in a thousand years for any of this to have any  
14 meaning, of course.

15 DR. CAMPBELL: But the waste packages  
16 ostensibly are -- oh, I'm sorry. I am incorrect, Ray.  
17 This is time sense waste package failure. This is  
18 1,000 years plus, and this was the initial amount of  
19 water coming into the package and reacting with the  
20 iron and stuff, and dropping the Ph down.

21 Then as more and more water and the  
22 reaction regresses with time, the sense of failure,  
23 you get a steady stay of environment if you will.

24 CHAIRMAN WYMER: But then you get into  
25 some questions like how much or what is the oxygen

1 partial pressure over that period of time, and is  
2 there enough iron in there to have for the first  
3 thousand years to have consumed all the oxygen coming  
4 in, and that would make a difference, too, of course  
5 to the whole chemistry of everything.

6 DR. CAMPBELL: I think that is an  
7 assumption on their part that the water is in  
8 equilibrium with the atmosphere and the drip.

9 CHAIRMAN WYMER: Which may be a bad  
10 assumption.

11 DR. SHEWMON: And the drip is in  
12 equilibrium with the atmosphere and the air above?

13 CHAIRMAN WYMER: Yes, that is an  
14 assumption.

15 DR. STEINDLER: Well, that one is not too  
16 bad. I mean, there have been enough experiments done  
17 in similar kinds of formations that showed the thing  
18 breaths fairly --

19 CHAIRMAN WYMER: Except that this has  
20 enough iron in it that it would consume oxygen for  
21 maybe a thousand years and still be some more left.

22 DR. STEINDLER: Well, that's what we mean  
23 by consuming oxygen.

24 DR. CAMPBELL: This is for the co-disposal  
25 packages, where you have high level waste glass. And

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1 again this is time sense failure of the waste package.  
2 So this is sometime after 11,000 years, in terms of  
3 repository time.

4 But the long term Ph that the system goes  
5 to is around 9, between 8-1/2 and 9. So you do have  
6 the higher Ph in the co-disposal package.

7 CHAIRMAN WYMER: The packages of high  
8 level waste from the very few processing plants and  
9 spent fuel are co-mingled. So that what you  
10 ultimately get in the aggregate is an average of these  
11 Phs based on the weight of the amounts and the  
12 relative corrosion rates.

13 And 10 percent of the waste approximately  
14 is glass logs, and the other 90 percent is spent fuel.

15 DR. CAMPBELL: Well, the co-disposal  
16 packages are interspersed with commercial spent fuel  
17 packages. The majority of packages are commercial  
18 spent fuel packages.

19 CHAIRMAN WYMER: Sure, 90 percent of them.

20 DR. CAMPBELL: But this is the in-package  
21 Ph. This is the package with the Ph inside a co-  
22 disposal package.

23 CHAIRMAN WYMER: There is no mingling of  
24 anything, no real mechanism for that.

25 DR. CAMPBELL: No, not in their model, and

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1 when you think about it, probably not in the real  
2 world, except in the invert itself. But we will get  
3 into that.

4 The way that they model the invert is  
5 basically diffusion through --

6 CHAIRMAN WYMER: Straight down.

7 DR. CAMPBELL: Yes, straight down  
8 basically.

9 CHAIRMAN WYMER: Well, I would think there  
10 would be a little lateral fusion.

11 DR. CAMPBELL: This is the commercial  
12 spent fuel degradation model showing the degradation  
13 rate that they use as a function of Ph in temperature.  
14 So at the higher Ph is the degradation rate, and it is  
15 lower than the lower Phs; and of course the  
16 degradation rate is higher at higher temperatures.

17 The cladding degradation model looks at  
18 the unzipping function, and the cladding creep, local  
19 corrosion, and actual physical failure of the cladding  
20 due to some seismic event or series of seismic events  
21 over time that cause material to fall on to or into an  
22 open waste package.

23 The calculation includes the seepage into  
24 and the temperature of the system.

25 DR. STEINDLER: Your prior one was the

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1 degradation of the spent fuel form itself.

2 CHAIRMAN WYMER: Are you going to go  
3 through all these view graphs, Andy? You are going to  
4 have to hurry if you are.

5 DR. CAMPBELL: Okay. Let me hurry up.  
6 Then the fraction of perforated cladding is shown on  
7 the following slide. So as a base, they are assuming  
8 a certain fraction of the cladding is perforated.

9 DR. SHEWMON: Now, is time zero from the  
10 failure of the waste package? So is this a hundred-  
11 thousand years after the 20,000 years?

12 DR. CAMPBELL: Paul, I don't know the  
13 answer to that, and whether this is real repository  
14 time, or post-waste package failure time for this  
15 cladding perforation.

16 DR. AHN: After this cladding from the  
17 reactor, there is an estimate of the initial phase,  
18 and it runs from one percent to 10 to the minus 2, and  
19 10 to the minus 3 percent.

20 Current DOE -- well, a couple of months  
21 ago, we used 8 percent failure initially for a waste  
22 package failure due to the -- during the interim  
23 storage period because of high temperatures.

24 Then they sophisticated a model a couple  
25 of weeks ago, and they were talking about 1.5 percent

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1 initial failure now.

2 DR. CAMPBELL: This blue line on this is  
3 8 percent by the way. And .1 would be 10 percent. So  
4 this would be a thousand, 10,000 and a hundred-  
5 thousand years after closure.

6 The next picture is just the variability  
7 of the cladding unzipping rate. So they are looking  
8 at a range of unzipping rates. The next figure is  
9 just --

10 DR. STEINDLER: Does that one make any  
11 sense?

12 CHAIRMAN WYMER: That's always a good  
13 question.

14 DR. STEINDLER: It seems to me that the  
15 unzipping rate should be a function of temperature.  
16 You are basically forming a high volume, and the only  
17 way you can get unzipping is really if you form a high  
18 volume --

19 DR. CAMPBELL: If you start corroding the  
20 fuel, right.

21 DR. STEINDLER: But that rate is a strong  
22 function of temperature. By the time you get to a  
23 hundred-thousand or 10,000 years out, that temperature  
24 is down fairly far. I wonder if that reaction still  
25 goes.

1           Because there are two kinds of reactions  
2 that take place. This isn't a simple oxidation to  
3 U308, for example, which was a cladding standard  
4 approach that the --

5           CHAIRMAN WYMER: It expands, and therefore  
6 it breaks it up.

7           DR. STEINDLER: Well, I don't think that  
8 is what you have got here.

9           DR. CAMPBELL: Well, that matrix  
10 temperature is taken into account in this, and that's  
11 why I put it back to that, and that is one of the  
12 inputs.

13           DR. AHN: There is another reaction, and  
14 that is hydroxide formation, even at the lower  
15 temperatures, can increase the volume, and I think  
16 that is what they are probably talking about.

17           DR. STEINDLER: You think that is what  
18 they are doing here?

19           DR. AHN: Yes.

20           DR. STEINDLER: Okay.

21           DR. CAMPBELL: This I just showed because  
22 I was amazed at the huge range of glass degradation  
23 rates that come out of this small uncertainty here,  
24 and it doesn't decrease with time.

25           DR. SHEWMON: Now, is that a dissolution

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1 rate, or what is this per year unit on a glass  
2 degradation rate? Is it fraction dissolved per year?

3 DR. STEINDLER: Well, the initial process  
4 is dissolution, but from there you quickly get the  
5 secondary minimum.

6 DR. CAMPBELL: Right.

7 DR. STEINDLER: But I think this is just  
8 the dissolution process that starts the formation of  
9 the other products.

10 DR. CAMPBELL: So you have about four  
11 orders of magnitude.

12 CHAIRMAN WYMER: And that is what it looks  
13 like on there, is one per year, and what is that  
14 symbol?

15 DR. AHN: It is a fraction per year.

16 CHAIRMAN WYMER: That is an F, huh?

17 DR. CAMPBELL: Fraction per year.

18 DR. CRAGNOLINO: It is one over a year.

19 CHAIRMAN WYMER: And you are going to get  
20 various silicates precipitated there.

21 DR. CAMPBELL: Yes, and they incorporate  
22 that in the model. I mean, their model does include  
23 all of that. The solubility model, and the main  
24 radionucleides that they look at are in terms of an  
25 actual solubility calculations are neptunium, uranium,

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1 and americium, as a function of Ph, PCO2, and again  
2 temperature in the in-package chemistry go into this.

3 CHAIRMAN WYMER: Does colloid formation go  
4 into it?

5 DR. CAMPBELL: Colloid formation comes  
6 after this, but yes. Let's see. What I am trying to  
7 do is just give you an overview of these, and how they  
8 are handling various aspects of --

9 CHAIRMAN WYMER: Well, they seem to  
10 discuss colloid in terms of what we normally call  
11 pseudo-colloids, and I haven't really seen colloids,  
12 per se, addressed.

13 DR. CAMPBELL: The main issue is as you  
14 say the pseudo-colloids.

15 CHAIRMAN WYMER: Who says?

16 DR. CAMPBELL: Plutonium to degradation  
17 products.

18 CHAIRMAN WYMER: Why is that assumed? We  
19 all know that plutonium forms nice colloids.

20 DR. CAMPBELL: There is a very large  
21 amount of glass --

22 DR. CODELL: I recall in one of the AMRs  
23 that the quantity of plutonium colloids is much  
24 smaller.

25 CHAIRMAN WYMER: Then that would be the

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1 explanation, the relative amounts, yeah.

2 DR. CAMPBELL: There is just a huge amount  
3 of colloids produced through degradation processes  
4 relative to view the natural system, or the true  
5 colloidal phases.

6 CHAIRMAN WYMER: Well, do people know what  
7 true plutonium colloids do with respect to forming  
8 pseudo-colloids? To me that seems kind of like a key  
9 question, because I think the first thing to form  
10 would be the true plutonium colloid. So that's the  
11 question.

12 DR. CAMPBELL: Well, a lot of this is from  
13 the glass degradation process, a lot of it.

14 DR. STEINDLER: What does it give to the  
15 other colloids?

16 CHAIRMAN WYMER: Well, there is a lot of  
17 solutious material in there.

18 DR. CLARKE: But how does it reversibly  
19 attach to another colloid starting out life as a  
20 colloid.

21 CHAIRMAN WYMER: Well, there is a lot of  
22 colloids.

23 DR. CAMPBELL: Now, this is one of the  
24 interesting aspects of the model, is this diffusion  
25 through cracks. If you -- and I haven't done it

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1 because you just end up with an infinite number of  
2 curbs.

3 But if you look at the DOE and TSPA  
4 results, there is a clear change around 40,000 years,  
5 and really before that period of time, between when  
6 the waste packages begin failing due to essentially  
7 stress corrosion cracking, to about 40,000 years, you  
8 have what they call a diffusion dominated system,  
9 where you have essentially small amounts of moisture  
10 diffusing into the waste package.

11 Then again the assumption is that that  
12 picks up radionuclides and diffuses out. What I  
13 haven't been -- and I am still trying to track down,  
14 is whether or not they are assuming that this waste  
15 package with this diffusion dominated period is also  
16 filled with 4-1/2 cubic meters of water. And I don't  
17 know if anybody has an answer to that.

18 DR. CODELL: Well, we had a technical  
19 exchange with DOE a month or so ago, I guess, where we  
20 batted several of these things back and forth, and we  
21 did some analyses on diffusion.

22 And we argued that DOE's model was way too  
23 conservative, and apparently they don't have or did  
24 not have it filled with water. The waste package  
25 isn't filled with water, but there is water film

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1 present.

2 And that essentially on the inside of the  
3 lid where you can get diffusion, the concentration of  
4 whatever is diffusing is at the solubility limit. And  
5 then it can diffuse through these stress corrosion  
6 cracks to the outside, whereupon it is carried away by  
7 liquid water.

8 Now, for this to happen -- and if you  
9 don't mind my going on -- the waste package must be  
10 tilted down so that the end cap is exposed up. That  
11 is, one of the supports must fail, and this seems like  
12 a low probability situation to me.

13 But it has to fail, because there is a  
14 lift around the welds which would prevent liquid water  
15 from the ceiling of the drip, to drip underneath that.  
16 And that is one of the mechanisms. You must have  
17 fresh water to carry this stuff away.

18 CHAIRMAN WYMER: Of course, the support  
19 time will be gone.

20 DR. CODELL: Yes, but it seems like at the  
21 very least half of them would fail, and then another  
22 half would fail. But it seemed like a low probability  
23 thing.

24 And then the other thing that really  
25 bothered me about it was that they allowed the

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1 diffusion to occur anywhere along the weld, wherever  
2 the crack might occur.

3           Whereas, it seemed like the only place you  
4 could really get diffusion would be at the bottom,  
5 because the path for diffusion from the fuel would be  
6 very tortious and very long, except maybe at the  
7 bottom where you might have some crud or sediment  
8 buildup, and you have a more direct category.

9           CHAIRMAN WYMER: Well, diffusion is one  
10 thing and capillarities is another.

11           DR. CODELL: Well, this is diffusion.

12           CHAIRMAN WYMER: Well, presumably you are  
13 getting some water moving all around through cracks  
14 and through edges by capillary action.

15           DR. CODELL: Well, they are talking only  
16 about diffusion. There are other phenomena here and  
17 that might be, but that isn't in their model.

18           DR. CAMPBELL: It isn't part of their  
19 model, and the other thing --

20           CHAIRMAN WYMER: It doesn't mean that it  
21 doesn't happen.

22           DR. CAMPBELL: No, and it may be that that  
23 process would dominate diffusion, but it is not in the  
24 current model. The interesting thing about the way  
25 they set up this diffusion model is the boundary

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1 condition is always zero concentration.

2 DR. SHEWMON: At the external surface you  
3 mean?

4 DR. CODELL: Yes.

5 DR. CAMPBELL: Right. So there is always  
6 a driving force, a maximum driving force, because in  
7 the real world you might have a diffusion radiant like  
8 that, but eventually that would level itself out  
9 because of the fact that diffusion would take place.  
10 And the other interesting aspect is --

11 DR. STEINDLER: It is a conservative  
12 assumption.

13 DR. CAMPBELL: It is a very conservative  
14 assumption. They don't take credit for degradation of  
15 that radiant. It is always the steepest that it can  
16 be.

17 And for all intents and purposes, since  
18 they are assuming that this film has some solubility  
19 limits and concentrations are similar to what you get  
20 in the big bath, as opposed to just the humid moist  
21 environment inside the waste package.

22 The model also assumes through the invert  
23 a boundary condition of zero concentration. So there  
24 is always a driving force, that once the material gets  
25 into the invert that it is always going to be

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1 diffusing towards the unsaturated side.

2 Now, the other model that they use --  
3 well, I have completely used other Marty's time here.

4 CHAIRMAN WYMER: Now you are 10 minutes  
5 into Marty.

6 DR. STEINDLER: Great.

7 DR. CAMPBELL: And the other model is the  
8 Advective model, where they use patches on top of the  
9 waste package. There are a certain number of general  
10 corrosion patches that are formed on top of the waste  
11 package that allows water in.

12 And as we already saw, the water fills up  
13 the waste package, and they assume that water comes  
14 out somehow or other, and an equal amount comes in and  
15 comes out.

16 For those conditions, you have -- well,  
17 this is kind of a cartoon of that, but advective flow  
18 through the invert. But this really doesn't become a  
19 dominant process until after 40,000 years, when there  
20 is a sufficient general corrosion rate occurring to  
21 allow enough open area on top of the waste package to  
22 allow a significant amount of water in.

23 CHAIRMAN WYMER: But that is assuming a  
24 11,000 year failure.

25 DR. CAMPBELL: Yes. Right. But as they

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1 grow those patches, they grow with time. In fact, an  
2 interesting outcome of their -- and it came up in the  
3 context of the TSPASR presentation a few weeks ago  
4 back in January, is that they do something called  
5 neutralization analyses to try and get a handle on the  
6 importance of different engineered systems.

7 And to do that they assume that a certain  
8 number of patches occur on all the waste packages very  
9 early on, but they don't grow with  
10 grow with time. So the degradation model, which  
11 assumes that those patches only grow with time, in  
12 fact in some long time frame, overtakes the  
13 neutralization analysis, in terms of dose, because the  
14 patches are still growing with time.

15 DR. SHEWMON: And this is all premised on  
16 a change in the ice glacial cycle, so that there is  
17 always water flowing through this place.

18 DR. CAMPBELL: The general consensus -- if  
19 I understand it correctly, the general consensus among  
20 people who study climate is --

21 DR. SHEWMON: The answer is yes; just yes  
22 or no.

23 DR. CAMPBELL: -- is that in the next  
24 2,000 years we are going to go into a glacial climate  
25 that is going to be around for many tens of thousands

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1 of years, 150,000 years or more.

2 So we are in an unusually dry period for  
3 Yucca Mountain.

4 CHAIRMAN WYMER: Aren't you glad you are  
5 going to be dead, Andy?

6 DR. CAMPBELL: Okay. Uranium solubility.  
7 These are just outputs of the TSPA model. This is  
8 time and package failure, and this is for commercial  
9 spent nuclear fuel. Again, this is being driven by  
10 that change in Ph that we saw for the spent fuel.

11 And this is for co-disposal. So this is  
12 the glass fuel. So the uranium solubility in the  
13 higher Phs is high. The colloid model assumes that  
14 you are generating colloids from the degradation of  
15 the waste forms, and that radionuclides are both  
16 irreversibly and reversibly attached to particles or  
17 a certain fraction of the colloid particles, say  
18 plutonium, for example, is always attached to it.

19 And with a certain fraction of the colloid  
20 particles that plutonium can really exchange with the  
21 aqueous environment. And then presumably if it is in  
22 the aqueous phase, it can then also attach itself to  
23 a mineral surface.

24 CHAIRMAN WYMER: If it is ionic, which it  
25 won't be.

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1 DR. CAMPBELL: Right. But in general  
2 then, the irreversibly attached or irreversible  
3 colloids move on average much more quickly than the  
4 reversible colloids, because you have some additional  
5 delaying mechanisms.

6 This just simply shows how they divvy up  
7 the -- how they do the colloids calculation. They do  
8 take in to account some measure of colloid stability.  
9 They have the colloids from high level waste glass,  
10 and from iron oxy, hydrochloride hydroxide, corrosion  
11 products, and from the natural ground waters.

12 And I think this again is hard to read,  
13 but what I wanted to show here was the role of  
14 colloids, and even on the hard copy it is difficult to  
15 read.

16 But anyhow it shows the plutonium as the  
17 fraction of plutonium for total release and then the  
18 reversible colloids. So at that point the whole idea  
19 here was to kind of give you a flavor for how the  
20 model is set up and some of the key areas of the  
21 model. And with that, Marty, I will turn it over to  
22 you.

23 DR. STEINDLER: I don't have anything left  
24 to say. That's fine. I did not look at the corrosion  
25 of the cladding, or the stainless steel can in which

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1 they poured glass, figuring that is a corrosion  
2 problem that I don't know anything about.

3 So we are going to ignore for the moment  
4 corrosion issues. I first tried to look at the source  
5 term, and that is what I have got for uranium.

6 You have got a radiated UO<sub>2</sub>, and we have  
7 a fair chunk of boron sulcate glass, and a literally  
8 dog's breakfast's worth of DOE spent fuel, largely  
9 metallic, but not entirely, and it contains things  
10 like carbide and non-uranium containing material.

11 DR. SHEWMON: Are we in class or are we in  
12 carbides, or both?

13 DR. STEINDLER: Both. Glass is strictly  
14 the defense high level waste --

15 DR. SHEWMON: I understand.

16 DR. STEINDLER: -- generated by carbide  
17 fuels, thorium fuels, et cetera, et cetera. There is  
18 a lot more obviously than commercial spent fuel than  
19 anything else, which is essentially UO<sub>2</sub>.

20 Water with unknown composition gets  
21 through the cladding or the outside container, and  
22 begins to react.

23 The first issue is in terms of release, is  
24 how much in the way of fission products and what kind  
25 have located in the cladding gap, and that is the gap

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1 between the spent fuel pellets and the cladding.

2 I wouldn't say that you can get any number  
3 that you want for that, but you can get quite a range,  
4 and I think that is not very well defined. For the  
5 most part, some iodine and -- a fair amount of iodine  
6 and some technetium is brought out by that process.

7 Let me make a couple of other points. As  
8 I mentioned, if you fish in UO<sub>2</sub>, you liberate two  
9 oxygens, and half of those, one of those oxygens, is  
10 taken up by fission products whose oxides are  
11 essentially more stable than UO<sub>2</sub>.

12 And that generally takes place even in hot  
13 water reactor fuel, and certainly takes place in fast  
14 fuel that has a much higher internal temperature.

15 The other half of that oxygen gets  
16 distributed between other fission products and  
17 decreasing free energy, or more likely becomes  
18 interstitial UO<sub>2</sub>, and it becomes interstitial oxygen  
19 dissolved in UO<sub>2</sub>.

20 The point that I am making is that the  
21 system tends towards being a reduced system, and in  
22 addition there is this epsom phase that we talked  
23 about before -- five component alloy, which is  
24 metallic, and contains some, but not necessarily all,  
25 of that terrible isotope called technetium.

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1 I have not seen too much discussion on  
2 that particular issue in any of the documents that I  
3 have read.

4 CHAIRMAN WYMER: Can I comment at this  
5 point?

6 DR. STEINDLER: Well, I was just going to  
7 make the other concluding issue, and that is in the  
8 long run, in terms of the entire inventory of  
9 available fission products, that may not make a great  
10 deal of difference.

11 And I haven't looked at it from that  
12 standpoint, but it could be the fact that nobody seems  
13 to care is because it doesn't make any difference to  
14 the downstream dose, which is really what people are  
15 focused on.

16 CHAIRMAN WYMER: I have talked to some  
17 people in France who do the reprocessing work, and  
18 they point out that there is always metallic  
19 technetium left in the dissolver when they dissolve  
20 that water in reactor fuel, and sometimes you can get  
21 as much as a third of all of the technetium that is  
22 present as undissolved material. And which is a  
23 difficulty in concentrated nitric acid with a  
24 catalyst.

25 DR. STEINDLER: And with a catalyst is the

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1 key.

2 CHAIRMAN WYMER: It is a very refractory  
3 material. So that is an ameliorating factor I think  
4 that hasn't even been considered, and it might reduce  
5 the technetium downstream.

6 DR. STEINDLER: Well, it gets us into the  
7 same discussion we had this morning, namely the  
8 assumptions that DOE is making are conservative, and  
9 as a consequence there isn't much point, I guess, to  
10 arguing about issues which would reduce the technetium  
11 content downstream or the rate. But it is a chemistry  
12 issue.

13 CHAIRMAN WYMER: It is a chemistry issue.

14 DR. SHEWMON: Is the iodine that is  
15 present after 10 or 20,000 years radioactive yet?

16 DR. STEINDLER: Yes. There is iodine-129  
17 which has a 15 million year half-life, which is the  
18 key -- well, the only iodine that --

19 CHAIRMAN WYMER: It is the only one of any  
20 consequence.

21 DR. SHEWMON: And the technetium is 99.

22 DR. STEINDLER: Yes, and it has a 200,000  
23 year, give or take, half-life. I realize that iodine  
24 has been well observed in the clad gap, but there is  
25 enough iodine to be tied up, and there is enough

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1 silver to be tieing up essentially all the iodine if  
2 they had a chance to get together.

3 And ultimately everything absolves, and so  
4 the question downstream into the unsaturated zone and  
5 beyond is what are the odds that iodide will react  
6 with silver that is migrating downstream. I have not  
7 seen much discussion on that one.

8 DR. SHEWMON: It all dissolves because it  
9 is infinite dilution finally.

10 DR. STEINDLER: Essentially. The thing  
11 that puzzles me is that we have been told repeatedly  
12 that the EH of that system is positive by a  
13 significant amount.

14 Yet, iodide is the only specie that  
15 anybody discusses, and that doesn't make a heck of a  
16 lot of sense. I don't understand why that has been  
17 maintained, again except for the fact that iodide  
18 moves downstream faster than anything else probably.

19 But as you pointed out early, Ray, it  
20 doesn't sound like good science, and you wonder what  
21 else is wrong.

22 CHAIRMAN WYMER: Certainly the  
23 observations have been that iodine whistles on through  
24 the --

25 DR. STEINDLER: Yes. But there is also a

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1 pile of iodate minerals that exist that are reasonably  
2 water stable, and so the opportunity for maintaining  
3 a decent stability with low solubility of an iodine  
4 oxygen compound strikes me as existing.

5 And I don't know whether that is an issue  
6 either, except that it doesn't seem to hang science  
7 together again.

8 CHAIRMAN WYMER: One of the problems with  
9 iodine is that it does not form many highly insoluble  
10 components.

11 DR. STEINDLER: Not too many.

12 CHAIRMAN WYMER: Copper iodide is one of  
13 the winners, and having said that, you have run the  
14 course, unless you get into these more complex  
15 minerals that have iodine tied up with them, which  
16 formations doesn't seem entirely likely. So iodine is  
17 always a problem.

18 DR. STEINDLER: Well, there are a couple  
19 of iodates that are fairly insoluble. Whether or not  
20 -- and iodates with fission product positive ions, and  
21 so whether or not they exist --

22 CHAIRMAN WYMER: And I agree with you on  
23 the anomaly of assuming iodide in --

24 DR. STEINDLER: Well, let's be fairly  
25 clear that the thing that dissolves out of this whole

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1 mess that people are interested in, or at least  
2 transports, is technetium, iodine, neptunium, and  
3 plutonium, as the first-line important nucleides.

4 CHAIRMAN WYMER: And one of the principal  
5 liberating factors is the formation of the  
6 tricarbonite, and you get it out of the way to release  
7 these things.

8 DR. STEINDLER: Yes. And there is some  
9 Carbon-14, and much further down, you begin to  
10 generate and transport downstream things like radium.

11 Okay. We have discussed ad nauseam the  
12 whole question of what kind of water do we have. We  
13 won't have J-13 water. The models don't, I think, do  
14 a good enough job that I can see -- whatever that  
15 means -- in addressing trace elements, and their  
16 behavior with very low concentrations of the things  
17 that we are interested in.

18 So the solution process that we are  
19 talking about here forms materials of concentrations  
20 that are really far down in the mud. Solubility  
21 limited concentrations are really quite small.  
22 Somewhere I have got a list of them, but it is  
23 probably for this discussion not particularly  
24 important what the actual magnitudes are.

25 It is that the abstraction that DOE has

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1 gotten into, and which apparently works well enough  
2 for them and the staff so that the staff has not  
3 objected too strongly, is that rates are fundamentally  
4 Ph driven, aside from temperature, if oxygen and CO2  
5 are controlled, when they are controlled by  
6 atmospheric concentrations.

7 That's not totally true for glass, where  
8 silica is an important influence in the rate. But  
9 essentially these are Ph driven dissolutions. They  
10 seem to work reasonably well.

11 Glass dissolutions have a strange set of  
12 kinetics as you know. But for the purpose of a  
13 repository type material, glass is a fairly modest  
14 contributor to the total isotope pushed downstream.

15 Some people don't seem to get too badly  
16 bent out of shape about the fair uncertainties in the  
17 case of glass.

18 CHAIRMAN WYMER: Well, the saving grace,  
19 of course, with the glass is that the plutonium has  
20 been taken out.

21 DR. STEINDLER: Yes, but you do have a lot  
22 of neptunium in places, and also a lot of technetium.

23 CHAIRMAN WYMER: That's right.

24 DR. STEINDLER: You have got a lot of  
25 technetium everywhere, except for cement in the river.

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1 CHAIRMAN WYMER: Well, there is very  
2 little burnt up stuff, and so a lot of these things  
3 are not there.

4 DR. STEINDLER: It's not a particular  
5 issue. Okay. What else is there of real importance?  
6 Oh. The fission products that move downstream that we  
7 are not interested in are believed to arrive in  
8 solution by simply congruent dissolution of UO<sub>2</sub>.

9 I think that is probably not a bad  
10 assumption. Besides, it doesn't make any difference,  
11 because we are not watching them. I mean, they are  
12 not contributors to the dose. They are elemental  
13 contributors, but they are not contributors to the  
14 dose.

15 Colloids are a different story, and Andy  
16 has kind of outlined what the colloid situation is.  
17 There are two kinds of colloids; those in which there  
18 is a reversible absorption, and colloids which are  
19 nominally called irreversible, but it is not  
20 absorption. It is co-precipitation.

21 CHAIRMAN WYMER: Those are pseudo.

22 DR. STEINDLER: Well, whether they are  
23 colloids or pseudo colloids reminds me of how many  
24 angels can dance on the head of a pin.

25 CHAIRMAN WYMER: Well, if you are going to

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1 talk about reversible and irreversible, then it has  
2 got to be pseudo colloids.

3 DR. CLARKE: Reversible or irreversible?

4 DR. STEINDLER: There are two kinds of  
5 reversible colloids.

6 DR. CLARKE: I think that's right. There  
7 is a different term in different documents for the  
8 same thing.

9 DR. STEINDLER: Yes. Glass is really the  
10 only source of minerals to which you get co-  
11 precipitation, which becomes irreversible. The others  
12 are all obtained from fuel.

13 There is a bucket of secondary products,  
14 and I simply want to reiterate my puzzlement that in  
15 the DOE models, commercial spent nuclear fuel  
16 dissolves to form copper minerals.

17 CHAIRMAN WYMER: Do what?

18 DR. STEINDLER: To form copper minerals.

19 CHAIRMAN WYMER: That's a novel trick.

20 DR. STEINDLER: Well, I thought that was  
21 kind of an interesting trick, and so I read it again,  
22 and it is there. What I haven't found where the  
23 source is.

24 And if you are old enough, you recognize  
25 that plutonium at one time was hidden under the code

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1 word copper. But you have to be even older than Ray  
2 in order to --

3 CHAIRMAN WYMER: Nobody is older than me.

4 DR. SHEWMON: Hardly a man is now alive  
5 that remembers that famous day and year.

6 DR. STEINDLER: You're right. And then  
7 they had to distinguish between copper and honest to  
8 god copper when they wanted to talk about real copper.

9 And in the case of fuel, they do form lots  
10 of silicates. The oxides and hydrous oxides,  
11 depending on what Ph range you are in, of plutonium,  
12 and an oxy carbonate for plutonium, or Neptunium-5, is  
13 an important actor in this thing.

14 In the case of solid products, and in the  
15 case of things like glass, obviously include borates,  
16 because you have got boron sulfate glass, and nothing  
17 is particularly surprising.

18 So as this soup dissolves, I hand to Jim,  
19 moving into the unsaturated cell, a pretty dilute  
20 aqueous solution, which is basically a carbonate base.  
21 It has got a Ph, depending on where and when you are  
22 looking at it.

23 And it varies -- what did we say -- from  
24 4 to 8 about. It has colloids in it that are  
25 important to the folks downstream. It will have

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1 technetium, claimed to be entirely as Technetium-7,  
2 rapidly moving with the waterfront.

3 And the same thing with iodine. A large  
4 fraction of the neptunium is Neptunium-5, which in the  
5 absence of a large amount of carbonate, will also move  
6 the waterfront. And that is basically what I hand  
7 you.

8 CHAIRMAN WYMER: And all these things are  
9 modified by whatever secondary phases are formed on  
10 the surface of the fuel that will attenuate, absorb,  
11 or otherwise diminish what comes out the bottom.

12 DR. STEINDLER: Well, I don't think there  
13 is much claim for excessive absorption on those  
14 mineral phases.

15 CHAIRMAN WYMER: There is not much  
16 claimed, but the question is how much is there.

17 DR. STEINDLER: That remains to be seen.

18 CHAIRMAN WYMER: I am not sure it matters,  
19 of course, because if they assume it all comes out,  
20 and it still looks okay, then what is the problem.

21 DR. STEINDLER: Well, what is the role of  
22 the colloids? The role of the colloids is that they  
23 move a lot faster than stuff that is absorbed and  
24 desorbed, especially with reasonably high distribution  
25 coefficients.

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1           So the concentration of colloids, and the  
2 concentration of actinides on those colloids get to be  
3 a big issue, largely lousy data, and that is my  
4 judgment, and not DOE's obviously.

5           I think the staff -- and to go back to the  
6 issues at hand, but I think the staff is aware that  
7 the data aren't very good. I have not delved hard  
8 enough into how loudly the staff is complaining that  
9 the data are not very good.

10           But it could make a significant difference  
11 to the downstream answer. The redux conditions I have  
12 already commented on. I am puzzled by what is  
13 elected, but I can understand if you want to be  
14 conservative, the election of a continuously oxidizing  
15 system can be justified reasonably well.

16           Whether you would find the technetium  
17 oxide or technetium sulfide that you could form would  
18 remain stable long enough to make any difference in  
19 the technetium downstream. I don't think there is  
20 enough answers on the ability to form technetium and  
21 its rate of oxidation in a system that is as dilute as  
22 the --

23           CHAIRMAN WYMER: The sulfate is very  
24 stable.

25           DR. STEINDLER: Right. We know that, but

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1 I have not seen any data on oxidation rates. There is  
2 some discussion in a bunch of these documents on the  
3 importance of the surface alpha radiation in modifying  
4 both the Ph, as well as the ionic content, which was  
5 a comment back there.

6 It isn't the gamma radiation, which at  
7 times is down to the point where it is fairly weak.  
8 It is strictly the alpha flux at the surface. The  
9 folks at the lab have looked at that, and I have not  
10 read their paper, and so I don't know whether that  
11 data is any good. I have to assume that it at least  
12 passed the referees.

13 I am a little bit disturbed frankly on a  
14 personal basis that trace elements in the water are  
15 not being considered adequately, and that may be  
16 unfair. I will have to look some more. But fluoride,  
17 it seems to me, complexes tremendously with  
18 plutonium.

19 Every good analytical chemist understands  
20 that. I don't see that recognition in the documents  
21 that I have looked at.

22 CHAIRMAN WYMER: And in an sufficient  
23 amount, it also precipitates it.

24 DR. STEINDLER: Yes, in those  
25 concentrations. But, I mean, at low concentrations

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1 you can get the Plutonium-4 monofluoride in solution  
2 that becomes inert fairly quickly. So if somebody  
3 assumes this stuff absorbed, maybe that is the wrong  
4 answer.

5 DR. SHEWMON: Inert means it won't absorb?

6 DR. STEINDLER: Right. I have looked at  
7 very few of the specific things that we were -- that  
8 I guess that I was supposed to have looked at, mainly  
9 what is the staff process and issue resolution.

10 But my contention is that the staff still  
11 thinks they are looking at science, and that they are  
12 asking questions which you would ask if you were a  
13 referee of a journal article; show me more evidence of  
14 a particular point.

15 CHAIRMAN WYMER: That's what I always say,  
16 is where is the data. Show me the data.

17 DR. STEINDLER: Fine. But what I don't  
18 see is -- and it seems to be rather broad, and the  
19 amount of information requested is substantial.

20 What I don't see is a follow-on sentence  
21 at the bottom of that saying the reason that we need  
22 this answer is because it makes a difference here,  
23 here, and here, and that influences your downstream  
24 dose. I don't see that connection too readily.

25 CHAIRMAN WYMER: Let me add a little

1 footnote to your fluoride discussion. There is in  
2 fact, but it amounts to a lot of getters for fluoride,  
3 in the rare earth. So it isn't always plutonium. It  
4 may be only a tiny fraction of it does, because  
5 obviously the insolubility of it varies in fluorides.

6 DR. STEINDLER: Right. Although I think  
7 the oxides are more stable than the fluorides in that  
8 solution.

9 CHAIRMAN WYMER: Depending on the  
10 solution.

11 DR. STEINDLER: Yes, depending on the  
12 solution or in this system. That in a very truncated  
13 fashion is my view of the world, a very narrow slice  
14 of a narrow slice. What have I left out, Andy? I'm  
15 sure that I have left out lots.

16 DR. CAMPBELL: You mean that I am supposed  
17 to play --

18 DR. STEINDLER: No, but aren't you part of  
19 my issue resolution problem?

20 CHAIRMAN WYMER: Well, I don't see a whole  
21 lot of sense in me going on at any great length about  
22 the in-drift chemical environment which we have been  
23 discussing directly and indirectly since this morning  
24 -- and we all know that --

25 DR. STEINDLER: Well, let me just make one

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1 comment. Do I sense -- if I address the question,  
2 does it look like the staff is holding DOE's feet to  
3 the fire adequately so that at least in the narrow  
4 area of chemistry of the fuel dissolution process, the  
5 in-waste form chemistry, that the answers are likely  
6 to be correct and good enough for what is to be done,  
7 but they won't pass a journal article referee?

8 I think that my tentative answer is, yes,  
9 I think the staff has got a fair handle on what the  
10 system looks like, and what it ought to look like, and  
11 what DOE is doing in order to describe it.

12 CHAIRMAN WYMER: Well, we now really are  
13 talking about the discussion of issue resolution key  
14 concerns here, which --

15 DR. STEINDLER: Have I jumped in the wrong  
16 place?

17 DR. CAMPBELL: No, it is the right place.

18 CHAIRMAN WYMER: But I think that's right.

19 DR. STEINDLER: And that is my very rough  
20 view.

21 CHAIRMAN WYMER: That's where I would call  
22 it, too. I think it is a statement that we have  
23 discussed informally earlier, that the issue  
24 resolution process as it is structured doesn't really  
25 have much opportunity for input other than what DOE

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1 brings us as their answers to the issue resolution,  
2 and then the response that the NRC has, and who says  
3 I need more information, more data, and where in the  
4 world did you ever get that conclusion from.

5 But it is very encouraging to me that the  
6 NRC staff has gone outside that box, and said, for  
7 example, have you guys considered secondary phase --  
8 and this is NRC and the center -- and have you  
9 considered secondary phase formation, and don't you  
10 think it is important.

11 And DOE says, no, we haven't, and it is  
12 not important, and then they start considering it.  
13 That goes outside the box a little bit, and that is  
14 really not within the formal issue resolution  
15 structure, because it wasn't an issue. It didn't come  
16 up.

17 DR. CLARKE: It would help me, Ray, if I  
18 understood better what the objective of the issue  
19 resolution process is. If the objective is to resolve  
20 issues that are on the table, that's one thing.

21 If the objective is more than that, then  
22 that is something else. So, you know, from what I  
23 have seen, I think the issues that are on the table,  
24 however they got on the table -- and I am new to this  
25 process, do get resolved, or aren't in the process of

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1 getting resolved.

2 CHAIRMAN WYMER: They do, yes.

3 DR. CLARKE: There is a good back and  
4 forth, and there is a spirited scientific exchange at  
5 these meetings, and I think all of that is very  
6 positive.

7 If the process is supposed to do more than  
8 that, and if it is supposed to from time to time  
9 revisit other issues, or if it is supposed to identify  
10 new things, then that's something else.

11 CHAIRMAN WYMER: Well, I would guess that  
12 it has changed over time with respect to what it did.  
13 I think initially there were -- that there was  
14 probably a flood gate of issues, and the flood gate  
15 was opened up, and out flowed the issues.

16 And DOE sat there and said, oh, my god,  
17 and it focused down after a while to where there was  
18 agreement by back and forth discussions between DOE  
19 and the NRC. And this is my perception, and if  
20 anybody in the room wants to say it is wrong, please  
21 do so.

22 DR. AHN: I would like to comment on the  
23 issues of the original process with a couple of  
24 examples. One is regarding the secondary minerals.  
25 We discussed this subject with DOE substantially.

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1           However, I don't think we need to be  
2 prescriptive to DOE. DOE has the flexibility to use  
3 their own methods to apply for a license. Therefore,  
4 as long as there current thought is conservative, or  
5 in other words, they don't give credit to secondary  
6 minerals, and not underestimate the performance  
7 objectives of the proposed 63, therefore, we do not  
8 ask in more descriptive ways for this particular  
9 subject.

10           Regarding the radionuclide effect, even  
11 though it will decay away after continual failure  
12 substantially, still there is the possibility on the  
13 surface of cladding from the residual gamma ray, and  
14 that may end up with a nitrogen cessation and lowering  
15 Ph and so on.

16           In the patch exchange, we raised those  
17 issues and DOE agreed to analyze that. Andy brought  
18 up today the Division 3 IRSR, and that IRSR included  
19 a background of all DOE's AMRs and PMRs, and the  
20 dissolution processes, and I included it, because that  
21 division was prepared after the issue of the  
22 dissolution exchange.

23           There are numerous subject concerns which  
24 we judge in the agreement for DOE to conduct what we  
25 asked them to do.

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1 CHAIRMAN WYMER: I didn't raise the point  
2 of secondary phase formation so much because I believe  
3 that DOE must have secondary phases, but to point out  
4 that in the NRC there is the ability and desire to  
5 think out of the box a little bit.

6 That they aren't constrained by this  
7 fairly -- what turned out to be a fairly formal issue  
8 resolution process at this point, and I am sure that  
9 has evolved to that over time with a lot of back and  
10 forths and agreements.

11 But now it is quite a formalized process,  
12 with very sharply defined key technical issues and  
13 subissues. But to me it was encouraging that  
14 something that was not actually an issue that was  
15 written down that somebody recognized was introduced,  
16 and it suggests to me that the staff and the centers  
17 are thinking creatively about this thing, and they are  
18 willing to throw something else in the hopper if they  
19 see it and think it is significant, and not to be  
20 prescriptive.

21 DR. STEINDLER: Ultimately, if my limited  
22 experience is any indication, both the staff, the NRC  
23 staff, and DOE, will stand in front of a Safety and  
24 Licensing Board Panel and defend themselves against  
25 the intervenors.

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1           It is at that point where you find out  
2           -- and I assume we will learn that before that point,  
3           but it is at that point that you find out whether or  
4           not both the staff and the NRC, and the DOE, have left  
5           anything out.

6           Because nothing could be more embarrassing  
7           it seems to me than to come to a licensing hearing,  
8           and prepared with 10,000 pages of documents apiece,  
9           and have somebody from the intervenors stand up and  
10          say, guys, you missed an important issue, and here it  
11          is, and you are in trouble.

12          CHAIRMAN WYMER: And because of that sort  
13          of thing, it seems to me that it would be -- that it  
14          is worthwhile for the NRC and the Center to  
15          periodically stand back. I know that they are all  
16          running like crazy just trying to keep up with things,  
17          and they are overworked and understaffed as usual.

18          But every once in a while some time should  
19          be taken to stand back and say, okay, we are emersed  
20          in this process, but now that we have explored all  
21          these issues, and we have exposed our mind to  
22          continuing an accumulation of facts, are there any new  
23          things, and to just take a minute, and sit back, and  
24          reflect on whether or not they really have covered the  
25          things that they should cover.

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1 DR. STEINDLER: Well, the Commissioners  
2 are certainly going to ask that of the advisory  
3 committee.

4 CHAIRMAN WYMER: Yes, and that is our  
5 role.

6 DR. STEINDLER: And they have a right to  
7 get a decent answer out of the advisory committee.

8 CHAIRMAN WYMER: But we are not in as good  
9 a position to do it as the staff is, because we are  
10 not steeped in the lore of the business.

11 DR. STEINDLER: I know, because you are  
12 independent.

13 CHAIRMAN WYMER: Yes, but the NRC is  
14 supposed to be independent.

15 DR. STEINDLER: No, I am talking about the  
16 advice that you give to the Commissioners. The  
17 Commissioners are going to say, you know, has the  
18 staff done -- and they probably care a little bit  
19 less, I assume, about DOE, but has the staff done a  
20 comprehensive job in looking at all of the necessary  
21 aspects of it so that they don't get blindsided when  
22 the intervenors stand up.

23 CHAIRMAN WYMER: And it seems to be this  
24 issue that we discussed earlier, and I will come back  
25 to it again as being important, that from the point of

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1 view of credibility, taking or wrapping too much up in  
2 bounding assumptions, or wrapping too much up in  
3 conservatism, leaves a point of attack open for  
4 intervenors.

5           They say that the science is not credible.  
6 Now, maybe this doesn't make any difference, but it is  
7 an argument that can be made. This is not a  
8 scientific method, and it doesn't take a whole lot to  
9 poison people's minds, and to turn their minds, even  
10 though it is down a blind alley, and they want to run  
11 down the blind alley.

12           DR. STEINDLER: I will have you know that  
13 the Atomic Safety Licensing Board Panels are not  
14 easily poisoned. I've been there.

15           DR. CAMPBELL: Ray, Tae Ahn has a point.

16           DR. AHN: Please don't misunderstand the  
17 prescriptive or what I mention to you. The fact is  
18 that in our TPSA code, we used secondary minerals in  
19 the distribution model, and we presented a background,  
20 and our base case model of spent fuel dissolution  
21 included secondary minerals. However, DOE did not.

22           We did not discuss that issue because DOE  
23 chose a more conservative approach. And I would like  
24 to inform you of that.

25           CHAIRMAN WYMER: And I think that is very

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1 encouraging personally that the NRC staff has included  
2 things in their code that are not in the original  
3 code, because that demonstrates independence.

4 And one of the real questions we have been  
5 asked is just how independent are these codes. Are  
6 they really taking different looks at the same thing,  
7 or are they taking the same look at the same thing.  
8 And the more dependence that you can demonstrate, the  
9 more comfortable I can be.

10 DR. AHN: And also there is another ACNW  
11 comment a year ago, and because DOE chose a very  
12 conservative spent fuel dissolution model, they ended  
13 up with giving credit to cladding. That introduced  
14 another system uncertainties.

15 On the other hand, we chose the realistic  
16 spent fuel dissolution model, and we took the  
17 protection of secondary minerals, and we do not need  
18 to credit cladding without introducing other  
19 uncertainties.

20 CHAIRMAN WYMER: If you can get a good  
21 result both ways as support.

22 DR. CAMPBELL: Well, let me chime in here  
23 about a problem that has been nagging me for a while,  
24 and in which I know at least one or two people on the  
25 staff are bothered by it.

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1           And it is in the context of DOE's  
2           neutralization analyses, and when they "neutralize"  
3           the waste package, which I briefly mentioned before,  
4           they get fairly high doses.

5           And when the NRC in their model does  
6           something equivalent to that, they get doses that are  
7           more than on an order of magnitude lower. And at this  
8           point in time, I do not see why in one case do you get  
9           doses up in the range of a rem when you "neutralize  
10          the waste package," even though it is understood that  
11          that is kind of an artificial process by DOE.

12          And when something similar in NRC's TPA  
13          code is done, and not even accounting for secondary  
14          phases, but just in terms of the release models and  
15          everything, and they neutralize the waste package, and  
16          they get doses in the range of 30 mill-rem, somewhere  
17          in that ball park.

18                 CHAIRMAN WYMER: That doesn't give you a  
19                 warm and fuzzy feeling does it?

20                 DR. CAMPBELL: But the question is why.  
21                 What is different about the approach that DOE is doing  
22                 with its model and what NRC is doing. And it is not  
23                 clear to me -- and I think part of the answer might be  
24                 this way they handle diffusion, setting boundary  
25                 values that are always zero.

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1                   But that may not be the answer, and I  
2 think that --

3                   CHAIRMAN WYMER: That was the mechanics of  
4 the neutralization? The way they do their sensitive  
5 tests?

6                   DR. CAMPBELL: It may be, but the question  
7 is has DOE and NRC going through a licensing process  
8 from the pre-licensing process, at some point this  
9 will come up as an issue, with what are the  
10 differences between the models and why should there be  
11 this kind of large difference?

12                   Is it some simple conservatism built into  
13 the DOE model that isn't built into the NRC model, or  
14 is there something more fundamental going on.

15                   CHAIRMAN WYMER: Do you want to address  
16 that?

17                   DR. CAMPBELL: In order to establish the  
18 credibility of that, there needs to be a better  
19 understanding of why those differences occur, because  
20 you get to the question of which is right.

21                   DR. CODELL: Richard Codell. Well, a lot  
22 of individualization analyses would probably answer  
23 it.

24                   DR. CAMPBELL: Well, I know that this has  
25 bothered Tim for a while.

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1 CHAIRMAN WYMER: And Tim doesn't know the  
2 answer either?

3 DR. CAMPBELL: I don't know if he does or  
4 doesn't, but I don't know the answer.

5 CHAIRMAN WYMER: Well, if it bothers him,  
6 he probably doesn't.

7 DR. CAMPBELL: It certainly is an area of  
8 concern, where you get these huge differences between  
9 the models which ostensibly represent the same basic  
10 system in slightly different ways, or maybe more than  
11 slightly different ways.

12 And when you do something similar with one  
13 model, and with the other model you get dramatically  
14 different results -- well, if there is an answer, I  
15 would like to hear it. Up to date, I have not heard  
16 a real good explanation for that.

17 And at first we were, frankly, a little  
18 shocked when we saw these utilization analyses come  
19 out. You know, why is that, and DOE has changed its  
20 model, and the design has evolved.

21 But fundamentally you are getting the same  
22 sort of dose versus time --

23 DR. SHEWMON: DOE gets the high value or  
24 the low value?

25 DR. CAMPBELL: The high, the high value.

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1                   CHAIRMAN WYMER: Now, John Kessler, and  
2 the contractors from EPRI have just very recently  
3 issued their total system performance assessment, and  
4 they pretty much agree with the DOE results and have  
5 come out with the conclusion.

6                   I don't know about this particular issue,  
7 but they came out with the conclusion that everything  
8 looks okay, but they are buying into the DOE's  
9 arguments that the waste repository is fine, but that  
10 is a total independent analysis.

11                  DR. CAMPBELL: You are talking about  
12 the --

13                  CHAIRMAN WYMER: Yes, it just came out.

14                  DR. CAMPBELL: But anyhow, with that  
15 scenario, and my scientific curiosity was tweaked a  
16 little bit by what aspects of how they are modeling,  
17 or differences between these two approaches to  
18 modeling in the system are driving those kinds of  
19 differences.

20                  Because at an early time frame, you are  
21 looking basically at the difference between something  
22 in the ball park of compliance and something that is  
23 really out of compliance.

24                  And it is only because the waste packages  
25 last that there are other things going on, but because

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1 the waste packages last for long time frames, past  
2 10,000 years, that this really isn't an issue.

3 CHAIRMAN WYMER: Well, Jim, why don't you  
4 launch into your presentation.

5 DR. CLARKE: Could we take a break, as I  
6 have to set up my projector.

7 CHAIRMAN WYMER: That sounds good to me.

8 (Whereupon, the meeting was recessed at  
9 2:27 p.m., and was again resumed at 2:40 p.m.)

10 CHAIRMAN WYMER: Okay. My name is Jim  
11 Clark. I am new to Yucca Mountain and new to this  
12 process. I recently joined the faculty at Vanderbilt  
13 University after 25 years in the private sector.

14 And my objective today is to provide an  
15 overview of the radionuclide transport, and I will  
16 call it issues and understandings as I know it. My  
17 understanding is increasing daily, and I am still at  
18 the connect-the-dots stage, and some of the dots  
19 appearing to be moving.

20 And so if I mis-speak, you know, please  
21 jump in. I know that John is here, and Bill, and  
22 anyone, please jump in and correct me. But basically  
23 I would like to just quickly overview the transport  
24 issues.

25 And my focus will really be on the

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1 transport processes, and not so much the actual  
2 modeling. But more of the processes and the issues.  
3 And then look at the key technical issue for  
4 radionuclide transport, the sub-issues, and the status  
5 of that situation.

6 And if we start out with -- and this is  
7 going to be hard to see, as this is from a paper in  
8 published literature. And is sort of a view from  
9 20,000 feet of Yucca Mountain, and from the transport  
10 side, we have the repository right in here, and we  
11 have about 300 meters below the surface, and we have  
12 an unsaturated zone again about 300 meters.

13 And then we have a compliance point about  
14 20 kilometers down gradient in alluvium, and here  
15 under the repository, and we have volcanic units,  
16 which are welded and non-welded just to give a very  
17 simple explanation, in the unsaturated zone.

18 We have a transition point between  
19 volcanic units and alluvium, the location of which is  
20 still uncertain, but there is work being done by Nye  
21 County that is attempting to reduce the uncertainty  
22 associated with that.

23 So, the repository, unsaturated zone,  
24 saturated zone, and alluvium, and a volcanic saturated  
25 zone, and alluvium. Andy spoke about the

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1 classifications that are being used for colloidal  
2 material, and we have had some discussion about that.

3 As I understand it, the irreversibly bound  
4 colloids are called true colloids, and the  
5 radionuclide is permanently over the time scale of  
6 interest, which is often long, are attached to and are  
7 really incorporated into the colloid.

8 So that the definition, Ray, I think  
9 really reflects the state of the radionuclide.  
10 radionuclide, and not so much the colloid; and a  
11 reversible bound colloid would be also what is called  
12 a pseudo colloid. Here the radionuclide can partition  
13 between the colloid, whether it is natural or waste  
14 form.

15 So part of the time it is present on the  
16 colloid, and part of the time it could be in a mobile  
17 aqueous phase, or it could be transported as a  
18 dissolved constituent.

19 CHAIRMAN WYMER: And I would argue that  
20 there is another colloid, which is a real colloid, as  
21 opposed to a true colloid.

22 DR. CLARKE: I am not going to argue with  
23 you. The transport assumptions maybe we should review  
24 quickly. If you are an irreversibly bound colloid,  
25 you are transported as a dissolved solute with respect

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1 to advection and dispersion in the zones of water that  
2 are moving.

3           However, there are a couple of rules. You  
4 are not permitted to diffuse into the rock matrix in  
5 zones where flow is fractured, controlled, and matrix  
6 diffusion is being considered.

7           And you can be attenuated through  
8 filtration processes which are being modeled through  
9 a retardation approach.

10           If you are a reversibly bound colloid,  
11 then you are transported as an IDC when you are bound,  
12 and as a dissolved solute when you are not.

13           DR. STEINDLER: Do you think as a colloid  
14 moves from an area of EH and PH ionic strength  
15 stability to one, where the principal is unstable, and  
16 then back, that that process will regenerate a  
17 colloid?

18           DR. CLARKE: I can't answer that. I am  
19 not sure how to answer that. I think stability issues  
20 are being considered from the standpoint of the amount  
21 of colloids.

22           And I think for the remainder of this  
23 presentation I am just going to be showing a few  
24 overheads.

25           CHAIRMAN WYMER: Let me ask you a

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1 question, Jim. In anything that you have run across  
2 did you see any discussion of what happens if during  
3 the transport of a colloid, however defined, is  
4 chemically altered by a reduction and what this does  
5 to the process, and whether that has even been taken  
6 into consideration?

7 For example, I read something that said  
8 humic substances in J-13 well water could affect the  
9 oxidation by reducing --

10 DR. STEINDLER: Isn't that an assumption  
11 on the part of DOE, that there are no colloids in the  
12 incoming J-13 type water?

13 CHAIRMAN WYMER: Oh, this would be in the  
14 humic acid materials that are present after --

15 DR. STEINDLER: I know, but they have  
16 defined them out of the system is what I am saying.

17 CHAIRMAN WYMER: Well, yes, out of the  
18 incoming system, but out of the emulgent system where  
19 you get into transport processes.

20 DR. STEINDLER: But there are no source of  
21 organics that they are willing to admit to.

22 CHAIRMAN WYMER: But it could affect  
23 oxidation, but there is no further discussion that I  
24 have seen.

25 DR. CLARKE: My understanding at this

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1 point, Ray, is that if you look at the reversibly  
2 bound colloids, they are being handled through a  
3 partitioning approach, Kd, and Kd has been developed  
4 for americium, and that is the one that is being used  
5 for those colloids that would be expected to be  
6 reversibly bound.

7 Now, as far as the chemistry beyond that,  
8 I really haven't come across anything, but that  
9 doesn't mean that it doesn't exist.

10 CHAIRMAN WYMER: Well, I looked at the big  
11 write-up on colloids, and they mention the possibility  
12 of there being organic acids down in the stuff beneath  
13 the drip.

14 But they don't say, okay, suppose we  
15 reduce the patched species, and we will chemically  
16 reduce it. What then? Certainly the whole picture  
17 changes, and with colloids that is potentially  
18 important.

19 DR. CLARKE: They are maybe being looked  
20 at as a process, and to the extent that is being  
21 incorporated into the model --

22 CHAIRMAN WYMER: But you haven't seen it?

23 DR. CLARKE: No, but that doesn't mean it  
24 isn't good.

25 CHAIRMAN WYMER: Well, that's true. There

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1 is so much literature on it.

2 DR. CLARKE: And again one of my concerns  
3 is that there does appear to be a fair degree of  
4 fragmentation among the issues, and some of the issues  
5 are obviously interrelated and is some critical  
6 interfaces.

7 The process -- it does appear that the  
8 objectives of the process do appear to be driving the  
9 reports and the format of the reports, so that you can  
10 in looking at an issue find those things that correct  
11 that issue.

12 CHAIRMAN WYMER: Okay.

13 DR. CLARKE: And there are process model  
14 points that are more comprehensive, and there are  
15 analytical model reports that are more focused. But  
16 I haven't seen anything that goes to both points.

17 In any event, just to very simplistically  
18 talk about the subsurface of the model, the  
19 unsaturated zone below the repository consists of  
20 welded tops and non-welded tops, and the welded tops  
21 would be treated as fractured systems, with the flow  
22 through the fractures.

23 And the possibility of a matrix diffusion  
24 into the rocks and matrix. The non-welded tops as I  
25 understand it are being treated more as a forest

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1 matrix, where there is flow through the rock matrix  
2 itself, with a distinction between areas which are  
3 zeolitic and which you would expect to have very high  
4 sorption and capacities in vitric areas. And that is  
5 just a very simplistic review.

6 I am going to skip over to the saturated  
7 zone, and again this is in the book. As I understand  
8 it, the saturated zone is being treated as below  
9 fracture control, or correction, flow and control, or  
10 at least everything that I have seen has indicated  
11 that.

12 DR. SHEWMON: Is the saturated zone below  
13 the water table?

14 DR. CLARKE: The saturated zone in the  
15 volcanic units, yes. The saturated zone in the  
16 volcanic units is being treated as fracture flow  
17 control, and the saturated zone alluvium has been  
18 treated as such, and so we have flow in the fractures,  
19 and various things that can happen.

20 We have vection in the fracture defusing  
21 into the so-called immobile water in the rock matrix,  
22 and it would be an attenuation process for  
23 radionuclides, and we can have sorption on the  
24 surfaces.

25 In principle, we can have sorption on the

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1 surfaces of the fractures, and we could have  
2 sorptions in the rock matrix. And I think depending  
3 on which model you are looking at, sorption in the  
4 shield is included or not on that kind of a scale.

5 And when you are in the alluvium, then  
6 this is being handled with an effective porosity, and  
7 these fracture flow models are really dual-porosity  
8 models, and that is the current approach.

9 And you have flow through with the whole  
10 matrix, with the potential sorption on the surface.  
11 You also have advection as well.

12 So that the major attenuation processes,  
13 at least two of the major attenuation processes would  
14 be matrix diffusion and sorption. And, for example,  
15 a fracture flow control domain, and if you had no  
16 matrix diffusion, you would have a flow moving in the  
17 fracture with some advection and dispersion.

18 If you have matrix diffusion, then you  
19 have attenuation of the radionuclides, and diffuse  
20 into the matrix, and the flow direction being this  
21 direction, and with the sorption and matrix diffusion,  
22 then you have a flow direction like this. And you can  
23 get significant attenuation through these processes.

24 It is hard to see the flow paths, but I  
25 think it is considered to be pretty much coming out of

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1 the repository and going to the southeast, and then  
2 coming back and going to the southwest, and that is  
3 about the predominant flow path based on not only  
4 hydraulic data, but in chemistry data as well.

5 I will say that in one of the meetings  
6 that I attended there was some concern about that, and  
7 there is some concern on the part of some that  
8 anything coming out of the repository could go deeper  
9 and into the saturated zone.

10 The other side of that story is that as  
11 you go into the saturated zone with depths, the  
12 vertical gradients are up. So that would support a  
13 plu coming out of repository and kind of riding the  
14 top of the water table.

15 DR. SHEWMON: And the gradient for what is  
16 upper?

17 DR. CLARKE: The vertical gradient.

18 DR. SHEWMON: For what?

19 DR. CLARKE: For what at different depths.

20 DR. SHEWMON: A change of something for  
21 what, for something?

22 DR. CLARKE: A change in elevation.

23 CHAIRMAN WYMER: Is it a gravity motivated  
24 process; is that what you are saying?

25 DR. CLARKE: No, I am saying that the

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1 force, if you will, would be upward.

2 DR. SHEWMON: Something is forcing the  
3 water upward through this medium, or are you talking  
4 about the transport or diffusion of an ion?

5 DR. CLARKE: I am talking about the  
6 pressure levels of the water.

7 DR. SHEWMON: It's either that I don't  
8 understand that, or it is so obvious that it is  
9 trivial. Go ahead.

10 CHAIRMAN WYMER: I have a little trouble  
11 with it, too.

12 DR. MCCARTIN: It is a gravity induced  
13 phenomena.

14 CHAIRMAN WYMER: Okay. That's what I  
15 said.

16 DR. SHEWMON: Well, it is a pressure  
17 grade, because of the gravitational field; and if you  
18 go down in water, the pressure always gets higher.

19 DR. MCCARTIN: This is higher than that.  
20 There is a connection between the upper and lower  
21 rock, such that you are maintaining a higher pressure  
22 for the lower output.

23 DR. SHEWMON: So one tends to permeate  
24 upward then?

25 DR. MCCARTIN: Yes.

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1 DR. CLARKE: If you put welds at different  
2 depths and measure water levels, you will find that as  
3 you go down the water levels go up.

4 DR. CLARKE: Okay. There is a flow model  
5 which drives the transport model, and what is called  
6 the particle tracking model. And again just an  
7 observation, and I am not sure what we can do about it  
8 in the short term, but there is a fair amount of data  
9 existing and data being generated through this work  
10 that would enable the calibration of the flow model.

11 The radionuclides are not in the system,  
12 and so we can't in the traditional sense calibrate a  
13 transport model. We can, however, look at the  
14 different pieces and the different processes, and use  
15 laboratory and field tests to get the best definition  
16 of those processes, and that is the approach being  
17 taken.

18 So the particle tracking method includes  
19 radionuclide transport processes of advection and  
20 dispersion, matrix diffusion in fractured volcanic  
21 units, and sorption.

22 Simulated flow paths occur in the upper  
23 few hundred meters of the saturated zone. And the  
24 they cross the 20 kilometer fence approximately 5  
25 kilometers west of the town of Amargosa Valley, which

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1 I think is a little bit south of Highway 95.

2 Now, again, the point at which the  
3 volcanic units transition into the alluvium is still  
4 an area of certainty, and that is important because of  
5 the attenuation that you would see in these systems.

6 And I thought that this might be  
7 interesting. Again, these overheads are taken out of  
8 various reports. The total system performance  
9 assessment-viability assessment, TSPA viability  
10 assessment, this is the information that was taken.

11 The matrix diffusion was modeled through  
12 what is called an effective porosity, where you have  
13 a fracture porosity, and a rock porosity, and you work  
14 within that range. But you treat the system with what  
15 is called a single continuum.

16 Dispersion was handled through a dilution  
17 factor, and the flow paths were one dimensional  
18 streamtubes; and if you go over to the current model,  
19 matrix diffusion is now being handled in what is  
20 called a dual porosity approach, an analytical  
21 solution, and dispersion being handled a different way  
22 as well.

23 And the flow paths from the 3-D process  
24 model --

25 CHAIRMAN WYMER: What kind of difference

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1 do these differences make?

2 DR. CLARKE: Well, the affected porosity  
3 model is compromised at best, and it would be  
4 difficult to handle a mixture of compounds with this,  
5 and factors for each radionuclide.

6 CHAIRMAN WYMER: I guess I was asking for  
7 the difference in results of the models. I mean, does  
8 it change the numbers that come out?

9 DR. CLARKE: I really can't answer that.

10 DR. STEINDLER: The answer is yes, it  
11 does.

12 DR. CLARKE: And again I would expect it  
13 to.

14 CHAIRMAN WYMER: A lot, a little,  
15 significantly?

16 DR. MCCARTIN: You mean between the two  
17 different types of models?

18 CHAIRMAN WYMER: Yes.

19 DR. CLARKE: I think his correction of  
20 specific prior assessment; is that right?

21 CHAIRMAN WYMER: Well, you prepared the  
22 two, and I wanted to know if it made much difference  
23 which one you used, and what the answer was that you  
24 got.

25 DR. MCCARTIN: It probably depends on the

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1 retardation coefficient that is being used. I mean,  
2 when something is really retarded, you change the  
3 retardation values.

4 I mean, there would still be some  
5 difference for the same retardation values, but if  
6 they also used a different model and different  
7 retardation values, you would probably be swamped by  
8 the retardation changes in the retardation.

9 CHAIRMAN WYMER: I can understand that.  
10 So perhaps the matrix diffusion might change the ratio  
11 of the materials that had different Kds.

12 DR. MCCARTIN: I am not sure what you  
13 mean.

14 CHAIRMAN WYMER: Well, I wondered if a  
15 semi-analytical solution changed the ratio of those  
16 materials that had a high Kd, and those that had a low  
17 Kd from the affected porosity model.

18 DR. MCCARTIN: Right. Yeah. Well, if we  
19 ran both models with the same Kd, there would be some  
20 difference between the two results.

21 CHAIRMAN WYMER: Maybe because of the  
22 change in the way they handle the ratio.

23 DR. MCCARTIN: Well, is the representation

24 --

25 CHAIRMAN WYMER: I think I am beating a

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1 gnat to death.

2 DR. CLARKE: I think it is fair to say  
3 that this is a much better representation of the  
4 system, with dual porosity.

5 DR. CAMPBELL: There are a lot of  
6 questions about effective porosity models.

7 DR. CLARKE: As I understand it, the  
8 models are different, and DOE is running its model,  
9 and you folks are running your model, and there are  
10 differences. But you are both taking a dual porosity  
11 approach to a matrix diffusion.

12 DR. MCCARTIN: Right.

13 DR. CLARKE: You are taking a kinetic  
14 approach.

15 DR. MCCARTIN: And we don't take much  
16 credit for it. I mean, it is all driven more by the  
17 assumptions of what is the fractured spacing, and what  
18 is the retardation in the matrix.

19 I mean, those are the things that tend to  
20 -- and I guess I am not aware of how much we have  
21 looked at the difference in any perimeters between the  
22 two of us. We will get to that, but the assumptions  
23 used in the model vary.

24 DR. CAMPBELL: Correct me if I am wrong,  
25 Tim, but if you use an effective porosity model, and

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1 essentially you have some distribution of porosity,  
2 and you say, well, my effective porosity is blah,  
3 blah.

4 Now, if you use some sort of dual  
5 continuum model, where the fractures say transit most  
6 of the radionuclides, and a particular sweep of those  
7 fractures is really good at transmitting  
8 radionuclides. And an effective porosity model  
9 wouldn't indicate that at all.

10 It would just say, you know,  
11 radionuclides are being transmitted at some effective  
12 retardation path, and you wouldn't be able to ferret  
13 out a particular set of features that might transmit  
14 it much more quickly.

15 CHAIRMAN WYMER: And presumably if you did  
16 your effective porosity calculations properly, you  
17 would get the same answer.

18 DR. MCCARTIN: Well, if you got your  
19 effective porosity based on flux, and most of the  
20 fluxes are fractures, you might be skewed to that end.  
21 I would have to work it out, but --

22 CHAIRMAN WYMER: I think I have a better  
23 grasp of it now.

24 DR. CLARKE: I'm sure that you can see  
25 this, Ray, but the effective porosity assumes that you

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1 have got porous medium at that porosity. And this is  
2 a much better representation. These models have  
3 evolved over the years as well, and has diffusion in  
4 the matrix and sorption.

5 CHAIRMAN WYMER: Okay.

6 DR. CLARKE: Okay. At this point. Let me  
7 just stop and share a couple of observations. Again,  
8 just based on where I am in this, all of these  
9 attenuation processes really delay the transport.  
10 They really are not irreversible. They delay the  
11 transport.

12 And from what I have seen, I think the  
13 work that has been done to demonstrate whether or not  
14 these processes are ones that would be expected to  
15 occur in this system has accomplished that. I think  
16 there has been a great deal of good work on both  
17 sides.

18 The unsaturated flow meeting in  
19 Albuquerque focused to a good extent on matrix  
20 diffusion issues, and I think the data would support  
21 the efficacy of that process and the system, and  
22 similarly for sorption clearly.

23 If there are going to be issues and  
24 controversies down the line -- and again I think I am  
25 just stating the obvious here. It is probably more

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1 not through these processes, and in fact attenuated  
2 radionuclides, and should we be looking at them.

3 And it is going to be more of a capacity  
4 issue, and what is the ability of the system to  
5 effectively attenuate the radionuclides, and to what  
6 extent can they do that.

7 The data are necessarily based on  
8 laboratory and field studies, and the laboratory  
9 studies do use site specific materials from what I  
10 have seen. I wouldn't say that they are overly  
11 conservatively designed. From what I have seen, they  
12 look pretty good.

13 And the field tracer studies again used  
14 surrogates to get information, but again I think the  
15 results demonstrate the process. The question is  
16 going to be scaling up, and how much of the system can  
17 we attribute to this.

18 That strikes me that that is going to be  
19 a function of how well this system is characterized,  
20 which is never enough usually. And so there are going  
21 to be some judgments about how much of this do we take  
22 credit for and in which region.

23 CHAIRMAN WYMER: I presume, Jim, that  
24 there is a whole tremendous -- say you take a tube  
25 down under the repository, and there is a lot of

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1 sorptive capacity just within a tube straight down.

2 You are never going to challenge the  
3 capacity of the medium to take up all the stuff that  
4 it sees. That's true, isn't it?

5 DR. CLARKE: Well, that would be right, I  
6 guess, at this stage. It really is a function of what  
7 goes into the system. I think that's why this  
8 interface is so critical.

9 And how much is going to be released and  
10 when is it going to be released, and what is the  
11 capacity of the system to attenuate it. If you look  
12 at the work that has been done, from what I can tell,  
13 it's not as if they don't need these natural barriers.  
14 That does not appear to be the case from what I have  
15 seen.

16 CHAIRMAN WYMER: What doesn't appear to be  
17 the case? Are you for or against it?

18 DR. CLARKE: Oh, no, no. They do need to  
19 take credit for these, and so the issue becomes how  
20 much. I mean, to me, again.

21 DR. SHEWMON: Why do you assume that there  
22 is enough active relevant surface?

23 CHAIRMAN WYMER: I didn't assume it, and  
24 that's my question.

25 DR. SHEWMON: Oh, that's your question.

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1 I thought that was a statement.

2 CHAIRMAN WYMER: I sort of tended to  
3 believe that since you have 300 meters of stuff down  
4 through there that there is enough capacity. But I  
5 don't know.

6 DR. SHEWMON: Well, it depends on what is  
7 there. I mean, if it were all lined with tungsten,  
8 nothing would happen.

9 CHAIRMAN WYMER: And presumably in the  
10 area where it is going through fractures  
11 predominantly, that washes out, and then it is only  
12 what is left that you have as a medium that has the  
13 sorptive capacity.

14 DR. CAMPBELL: One of the ongoing projects  
15 that DOE has is this -- what they call their busted  
16 view test, where they are using analogs, and trying to  
17 get a handle on the sorptive capacities and diffusive  
18 capacities of a formation underneath a repository  
19 called Calico Hills, which is a fairly -- well,  
20 portions of it are a fairly friable ash unit, where  
21 flow and transport occur through a porous medium, as  
22 opposed to fractures.

23 But not all of the area of the repository  
24 is over areas of the Calico Hills will occur. There  
25 are some fraction of the repositories over an area

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1 where it is a harder material, and it is more vetric,  
2 and it has more glass in it.

3 And there would tend to be more flow  
4 through essentially a fracture network. But a lot of  
5 the units are still fractured rock, and you are  
6 looking at flow through fractures.

7 CHAIRMAN WYMER: So the sorptive layer is  
8 really a fraction only of the total depth of this  
9 tube?

10 DR. CAMPBELL: Yes. And they build this  
11 into their model, and I think NRC does as well through  
12 having several sub-areas, or a half-a-dozen sub-areas  
13 of the repository, some of which to through a Calico  
14 Hills vitric, and some of it goes through the Calico  
15 Hills that can be more sorptive.

16 One of the issues is the temperature  
17 effects of the repository on the zeolytes, which are  
18 the reactive phase in that area, and the ability of  
19 those zeolytes to absorb the radionuclides.

20 CHAIRMAN WYMER: And it strikes me that  
21 there is a lot of competition for those sites, because  
22 you have an awful lot of steel, and you have an awful  
23 lot of uranium relative to the things that you really  
24 want to absorb, and I don't know how much these  
25 competitions have been looked into, or whether the

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1 capacity of the reactive tube is challenged.

2 DR. CLARKE: I haven't seen much on  
3 competitive sorption.

4 DR. MCCARTIN: Yes. It is really a dilute  
5 amount, but for our modeling, generally when you look  
6 at the unsaturated zone versus the saturated zone from  
7 a matrix diffusion standpoint, the velocities in the  
8 fractures in the saturated zone are relatively slow  
9 compared to the unsaturated zone just based on the  
10 grading.

11 So you have got 300 meters at most of  
12 saturated or unsaturated zone fractures, versus 15  
13 kilometers of fractures potentially, and maybe more,  
14 of fractures in the saturated zone, where velocities  
15 are slower.

16 And so for our model, as Andy knows, we  
17 have the ability to assimilate matrix diffusion in the  
18 unsaturated zone. We don't do it. Computationally,  
19 it is very taxing, and based on the travel times, it  
20 isn't going to have that big of an effect.

21 CHAIRMAN WYMER: There are just much  
22 saturates before you get to the bottom that who cares.

23 DR. MCCARTIN: But part of the benefit is  
24 totally tied to how much retardation there is. And  
25 the biggest thing in the unsaturated zone that I know

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1 when we were looking at could we support matrix  
2 diffusion in the unsaturated zone was that there were  
3 two things that we were aware of.

4 One was Chlorine 36, and the fact that  
5 Chlorine 36 got down there, and matrix diffusion was  
6 really a strong effect, maybe you shouldn't have seen  
7 that. And then Bill Murphy at the Center did a lot of  
8 work looking at fracture water versus matrix water,  
9 and he saw that there were just two completely  
10 distinct systems.

11 That they are just completely different  
12 chemistries, and once again if matrix diffusion was a  
13 strong influence, you shouldn't see this huge  
14 disparity between the fracture of water and the matrix  
15 water.

16 And I don't know if John -- well, I know  
17 that goes back 4 or 5 years, and I don't know if  
18 anything more has been learned from that. But with  
19 that information for the user at least, there was,  
20 well, how much do you really want to take credit for  
21 it when you have got 15 kilometers of fractures and  
22 matrix diffusion in the sat zone, with lower  
23 velocities, which makes it an even stronger effect.

24 DR. SHEWMON: Well, plutonium hit the fan  
25 so to speak a while back because if it migrated

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1 further out of a test site than others. They talked  
2 about it being colloidal, and the colloidal then flows  
3 only in the fractures, and it doesn't get caught up in  
4 the matrix, and it doesn't absorb, is that correct?

5 DR. MCCARTIN: Well, it doesn't have to  
6 flow just in the fractures. There should be some  
7 screening both in the matrix and --

8 MR. BRADBURY: Actually, Jim said that  
9 there are filtration processes that DOE takes credit  
10 for.

11 DR. CLARKE: Which is being handed through  
12 retardation. As I see it, there are four systems in  
13 the unsaturated zone. There is the fractured system,  
14 the welded tuff, and then there is the more porous  
15 system.

16 And I would agree that in the fractured  
17 system that you have got higher velocities, and you  
18 have the chlorine-36 data and you have all kinds of  
19 reasons not to get real excited about matrix  
20 diffusion.

21 You do have the porous rock, however, and  
22 you would expect some attenuation there. When you get  
23 into the saturates, you have a long stretch, and we  
24 don't know how long yet.

25 But you have got a long stretch of

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1 fracture flow control systems, where you have much  
2 slower velocities, and you have got much higher matrix  
3 diffusion potential and dispersion potential.

4 DR. SHEWMON: You are getting too general  
5 for me. I asked you specifically about the plutonium  
6 and the colloids, and why it was that it being a  
7 colloid all of a sudden explained the results.

8 DR. CLARKE: I'm sorry, Paul. I thought  
9 we had already answered your question, but the  
10 approach does permit removal or attenuation of  
11 colloids through a filtration process. Colloids are  
12 getting hung up as they are transported through the  
13 system.

14 DR. SHEWMON: Okay. And that is in the  
15 saturated or the unsaturated?

16 DR. CLARKE: That would be in both of  
17 them.

18 DR. SHEWMON: And is the filtration  
19 different from the matrix diffusion that you are  
20 talking about?

21 DR. CLARKE: Yes. And the filtration  
22 process really applies just to the colloids. The  
23 matrix diffusion applies to dissolved material  
24 solids, something moving through the system that now  
25 has a concentration grading between where it is in the

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1 fracture and in the much lower concentration in the  
2 rock.

3 DR. SHEWMON: But it is diffusing along  
4 very fine crevices; is that right?

5 DR. CLARKE: Yes.

6 DR. SHEWMON: It is mechanical diffusion.

7 DR. CLARKE: Yes.

8 DR. CAMPBELL: Paul, I think the question  
9 that you are asking -- and correct me if I am wrong --  
10 is why do colloids carry stuff faster than on average,  
11 and --

12 DR. SHEWMON: And the answer that I am  
13 getting is that they stay to the fractures pretty  
14 well.

15 DR. CAMPBELL: Because they tend to have  
16 a negative charge and the surfaces of the minerals  
17 tend to be negatively charged. So that through  
18 something called anionic exclusion, anionic species  
19 tend to be excluded from these very tiny pore spaces.

20 So they tend to stay in these larger pore  
21 spaces where the flow rates are faster. The amount of  
22 plutonium --

23 DR. STEINDLER: They don't stick to the  
24 wall.

25 DR. CAMPBELL: Right, they don't stick to

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1 the walls, and so you have a distribution of a flow  
2 rate, and it tends to move the stuff attached to  
3 colloids to the upper end of the distribution.

4 DR. CLARKE: Right. And if there aren't  
5 any velocity radiants, then the velocity is higher.

6 DR. CAMPBELL: One of the things to keep  
7 in mind about the migration of plutonium at a Nevada  
8 test site was that the specific area was a place  
9 called the Benum Test, and in one of the wells, they  
10 were able to identify plutonium by its isotopic  
11 signature as having come from that test.

12 It was about 1-1/2 kilometers from the  
13 test site. This is in the saturated zone, and it is  
14 well within the saturated zone. Actually, in a  
15 portion of the Calico Hills saturated zone, the  
16 amounts of what they call colloidal material were  
17 pretty small.

18 And we are dealing with large  
19 concentrations that are very low concentrations, and  
20 it wasn't just plutonium. There were a number of  
21 radionuclide, and what they did was that they filtered  
22 the water and these particles were filtered out at  
23 some sized fraction, which fell within the range of  
24 what is called colloidal.

25 But it not only included plutonium, but

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1 also cesium and some other stuff. And it was presumed  
2 that these were essentially natural colloids that  
3 these radionuclides had become attached to.

4 It has not been seen in a lot of the test  
5 sites, and so it has never been clear why that  
6 particular shot -- it was a big one. It was over a  
7 megaton -- produced this effect. But it is there and  
8 they did see radionuclides in this well that they  
9 didn't anticipate.

10 DR. MCCARTIN: And at one time I thought  
11 there was still some debate as to whether this  
12 occurred very shortly after the shock, and the  
13 transport. You know, this is not a long term  
14 transport problem, but this occurred very quickly  
15 after the shock.

16 CHAIRMAN WYMER: Yes.

17 DR. MCCARTIN: But I know that there was  
18 some discussion early on, but I haven't followed it  
19 for a while. But no one -- well, they found it, and  
20 it might have been there 40 years ago, but it was  
21 still there.

22 DR. SHEWMON: They just hadn't looked in  
23 that well?

24 DR. MCCARTIN: Yes.

25 DR. CAMPBELL: The group that does this at

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1 Los Alamos has been monitoring wells all over the test  
2 site for some period of time, and looking for  
3 migration in that.

4 And I will add that the issue of transport  
5 as a colloid is still open because of the way people  
6 measure or attempt to measure colloids. You can  
7 generate artifacts with that if you don't do a really  
8 good job.

9 There is some work that has been done  
10 actually by a group that I know about, because they  
11 are actually oceanographers that are doing it, both at  
12 Savannah River and Hanford, in which species that were  
13 thought to be colloidal transported plutonium, was in  
14 fact a transport of dissolved plutonium that was in a  
15 more oxidized state.

16 So there are artifacts that can be  
17 generated through the filtration processes that one  
18 has to be very careful about. Sometimes what appears  
19 to e colloidal transport isn't.

20 DR. SHEWMON: Thank you.

21 CHAIRMAN WYMER: Enough already.

22 DR. CAMPBELL: Those are some of the  
23 uncertainties --

24 CHAIRMAN WYMER: Jim, what else have you  
25 got there?

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1 DR. CLARKE: Maybe I can just transition  
2 into the issues and sub-issues.

3 CHAIRMAN WYMER: I would add that I do  
4 think that the whole question of colloids is one that  
5 is going to be brought up, and it is going to be a  
6 point in which the intervenors and citizens are going  
7 to grab a hold of and say what about this, and so I  
8 think it is an important issue.

9 DR. SHEWMON: But you don't mean to imply  
10 that it isn't being dealt with?

11 CHAIRMAN WYMER: No, I do not mean to  
12 imply that it is not being dealt with. I mean just to  
13 stress the importance of it.

14 DR. CLARKE: Okay. The radionuclide  
15 transport key technical issues, and there are four  
16 sub-issues. I have done nothing on sub-issue number  
17 four. So we will not be talking about that today.

18 But as far as the first three sub-issues,  
19 the system has essentially been organized under porous  
20 rock, and this would be floating through the rock  
21 matrix, and the alluvial, which again would be treated  
22 as a porous medium, and radionuclide through fractured  
23 rock.

24 Again, Tim, maybe you can help me with  
25 this, but as I understand it, porous rock is being

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1 addressed in the unsaturated zone, and the saturated  
2 zone is primarily being looked at, if not exclusively,  
3 as fractured in the volcanic units.

4 DR. MCCARTIN: In volcanic.

5 DR. CLARKE: In volcanic, and of course  
6 the alluvial after that should be treated as a porous  
7 medium. So that is the way that these issues are  
8 organized.

9 CHAIRMAN WYMER: Do you see any gaps in  
10 it?

11 DR. CLARKE: No. I think that covers the  
12 system. You could organize it differently, but I  
13 think that is everything. All of these issues are  
14 what is called closed pending.

15 I believe we went into the meeting at  
16 Berkley with the first three open. Were they all  
17 open, Tim?

18 DR. MCCARTIN: Yes.

19 DR. CLARKE: But in any event, they are  
20 all closed pending on it. I thought I would just show  
21 a few. It is going to be hard to see these, but I  
22 think --

23 DR. CAMPBELL: Everybody has a hard copy,  
24 Jim.

25 DR. CLARKE: Okay. Really, the only

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1 reason I wanted to show these was just to give you a  
2 feel for the kinds of things that come up in this  
3 issue resolution. And it strikes me that they can be  
4 pretty much be organized into requests for additional  
5 documentation, requests for more justification.

6 And in some cases the data simply haven't  
7 been developed yet, which is the case with the  
8 alluvial, where there is an ongoing investigation to  
9 not only determine transitions, but also to look at  
10 the characteristics and other features of it as well.

11 So these tend to be the requests that come  
12 out of that. For example, radionuclide transport  
13 through porous rock, the first one, is provide the  
14 basis for the proportion of fracture flow through the  
15 Calico Hills non-welded vitric.

16 Provide analog radionuclide data from  
17 tracer tests for Calico Hills at Busted Butte, which  
18 Andy spoke to before. So in many cases the data are  
19 there. They just need to be provided.

20 Provide the screening criteria for the  
21 radionuclides selected for PA.

22 CHAIRMAN WYMER: This just pertains to  
23 colloids apparently, number three.

24 DR. CLARKE: I thought it was more general  
25 than that. Are these not two separate questions; one

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1 is the list of the radionuclides that will be the  
2 model, and the other is --

3 DR. CAMPBELL: Those radionuclides that  
4 can be associated with colloids. So what DOE -- if I  
5 can remember correctly, what DOE agreed to do was in  
6 their inventory of fraction AMR they are going to  
7 apply the basis for screening out particular  
8 radionuclide.

9 And then the AMR on waste form colloid-  
10 associated concentration limits, they are going to  
11 provide their argument for why they are only focusing  
12 on a few key radionuclides, in terms of colloid  
13 transport.

14 CHAIRMAN WYMER: Yes, that's what I read  
15 it to say.

16 DR. CLARKE: And as you can see, there are  
17 a number of issues on the alluvial, given the status  
18 of that program, and to provide further justification  
19 for the range of effective porosity in alluvium.

20 The other thing that I should say is that  
21 the way these model predictions are done, at least on  
22 the DOE model, is that the parameters that drive the  
23 flow of transport or transfer, and let's talk about  
24 that, are handled either by what is called bounding.

25 In other words, there may be some

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1 perimeters that have constant values for the region in  
2 which the calculation is being performed, and then  
3 there are a number of perimeters that are handled  
4 statistically.

5 So the distribution is set up for these  
6 perimeters, and this is not an uncommon way to do  
7 these predictions, and then the distribution of sample  
8 in the process.

9 It strikes me that most of the perimeters  
10 are handled statistically and certainly all of the  
11 ones that we considered sensitive to those  
12 calculations.

13 Provide a detailed testing plan for  
14 alluvial testing at the alluvial testing complex, and  
15 again these are the kinds of questions that are being  
16 asked and the agreements that are being made.

17 And I think this kind of speaks for itself.

18 DR. CAMPBELL: You certainly don't need to  
19 go through each and every one of these agreements.

20 CHAIRMAN WYMER: I think one of the  
21 significant things that comes out is that there are an  
22 awful lot of requests for trivial data and for  
23 documentation, which I think is sort of typical of the  
24 approach that is used in these issue resolution  
25 meetings. NRC is always saying show us the data, and

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1 show us the documentation.

2 DR. CLARKE: It strikes me that while  
3 other things do come up and get discussed from time to  
4 time, at least these meetings are very focused and  
5 very focused on the issues. I am not saying that is  
6 either good or bad, but that is the nature of the  
7 meetings.

8 CHAIRMAN WYMER: Well, one thing that  
9 bothers me a little bit about this aspect of the  
10 process was that very often DOE will say, okay, there  
11 is an AMR available that discusses that, or we will  
12 give you one at the next meeting.

13 And that sort of leaves it hanging. You  
14 aren't really dead sure that that AMR they referred to  
15 has really got the stuff in there, and that kind of  
16 bothers me. You have to sort of take it on faith.

17 DR. CLARKE: Well, as I mentioned before,  
18 the issue of the documents being generated at least to  
19 resolve these issues, and they are very focused on  
20 doing that, just resolving these issues.

21 So information is brought in from whatever  
22 sector it needs to be brought in from to address the  
23 particular issue. One of my concerns, and really it  
24 may be unfounded, but one of my concerns is that the  
25 issues are fragmented.

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1           There are a number of issues and a number  
2 of sub-issues, and there are some critical interfaces.  
3 At some point in the process, if it is not already  
4 being done, I think there would be a great deal of  
5 merit to pulling together more comprehensive -- and  
6 what I would call technical basis documents.

7           And which would not only deal with flow in  
8 the saturated zone, or radiated flow transfer, but  
9 would deal with source terms, and other things that  
10 need to be dealt with across an interface.

11 I don't see that now. It may be out there, but I  
12 haven't seen it yet.

13           CHAIRMAN WYMER: We talked about that a  
14 little bit, and that up to a point, that is handled in  
15 the building materials. But things get so abstracted  
16 at that level that you aren't exactly sure that things  
17 really have been handled across the interface  
18 properly.

19           DR. CLARKE: Also, I think it would be  
20 helpful if it is not already being done, but the  
21 people working on the radionuclide transport key  
22 technical issues, to be up to speed on what is going  
23 to go into the sub-surfaces as a result of near-field  
24 processes, container lifetime --

25           CHAIRMAN WYMER: Yes.

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1 DR. CLARKE: And it may be that you have  
2 to get to the TSPA level to get the total treatment,  
3 but I can't tell. But I think there is a lot of  
4 synergy there, and a lot of good reasons to work  
5 across that interest.

6 DR. CRAGNOLINO: I want to make a point.  
7 This is precisely the idea what is going to be called  
8 a degraded high -- and that means that all of the  
9 integrated parts of the evaluation of a repository are  
10 going to be linked together in different ways.

11 CHAIRMAN WYMER: But that's quite a ways  
12 in the future is it not?

13 DR. CRAGNOLINO: No. It is going to be  
14 issued in September. We are preparing the outline,  
15 and trying to focus a way to integrate it in different  
16 processes.

17 CHAIRMAN WYMER: One of the points that  
18 the NRC has hit on time and again is with respect to  
19 the total system performance assessment, because we  
20 don't understand it. It is so big and so grandiose  
21 that we can't wrap our minds around it.

22 We have not been emersed in the details  
23 and so we don't have the background to bring to it,  
24 and which you people are steeped in, and therefore,  
25 what we have been saying time again and time again is

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1 to simplify, simplify, and it is hard to simplify  
2 something that is inherently complex.

3 But I guess I would say the same thing  
4 about an integrated resolution document; that it has  
5 to be understandable not only to the real experts in  
6 the field, but to people who have to get a warm fuzzy  
7 feeling when they read it.

8 And when they read it, feel that things  
9 are all right here, and that I understand it and it  
10 looks pretty good. It is a real challenge to do  
11 something that way and still cover the technical  
12 issues.

13 But if you don't do it, some of us are  
14 just going to keep hammering on it, whatever that  
15 amounts to.

16 DR. CLARKE: I guess the other thing that  
17 I would suggest if it is not already out there or  
18 being worked on, and in response to the concern that  
19 Andy raised earlier, would be a blow-by-blow  
20 comparison of the assumptions in each of these  
21 different models, and the expectations as to how those  
22 assumptions would affect the final outcome.

23 MR. BRADBURY: Let me give you an example.  
24 This figure that you put up before on the use of  
25 hydrochemistry and the flow path. It is fascinating,

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1 because what it does is the lines, the flow lines,  
2 essentially connect lines of equal concentration of  
3 conservative constituents -- chloride, sulfate -- and  
4 those are the ones that I consider conservative, and  
5 there are other ones maybe, but maybe not.

6 And so they are saying that the  
7 concentrations of these constituents remain constant  
8 along these flow lines. That assumption then says,  
9 well, forget about dissolution along the flow path.

10 It is a very big assumption; that they  
11 must therefore for consistency sake carry that through  
12 and include that assumption also in their performance  
13 assessment, or they don't use hydrochemistry in this  
14 way to delineate the flow path.

15 It is a very powerful assumption, and I am  
16 not sure whether they have actually thought that far.  
17 Well, let me put it this way. That definite changes -  
18 - and that was surprising to me when it was pointed  
19 out this way.

20 CHAIRMAN WYMER: Well, I picked that up  
21 from the --

22 DR. CLARKE: Well, I ran the risk of using  
23 it as an example of something else, and looking for a  
24 good graphic that showed the flow paths as they are  
25 currently understand. I know that is a controversial

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1 issue.

2 DR. STEINDLER: But that is a conservative  
3 assumption.

4 DR. CLARKE: Right.

5 DR. STEINDLER: I mean, that is very  
6 conservative.

7 CHAIRMAN WYMER: No, highly, highly  
8 unlikely.

9 DR. STEINDLER: The question is whether or  
10 not the staff should hammer at DOE, the NRC staff  
11 should hammer at DOE to justify what I think all  
12 parties would agree is a very conservative assumption.  
13 And that usually gets the guy right up out of the  
14 chair.

15 MR. BRADBURY: Actually, I think it is  
16 conservative, but what if these aren't the flow paths  
17 then? What if there is dilution, and Steve Hanaver  
18 raised this issue before. Normally, they assume that  
19 there is this evolution of the composition of water as  
20 it moves through the rock.

21 And so this is going against normal -- the  
22 scientific community's normal assumptions, and so you  
23 might have to think different. Well, if you have  
24 different flow paths, how does that impact  
25 performance.

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1 DR. CLARKE: It is conservative from a  
2 dose standpoint, but if they give you the wrong  
3 answer.

4 MR. BRADBURY: Well, are the paths  
5 perpendicular to these? I don't know if they are or  
6 not.

7 DR. SHEWMON: It doesn't make a  
8 difference.

9 MR. BRADBURY: I don't know the answer to  
10 that.

11 DR. SHEWMON: I assume that the staff's  
12 focus is what goes on at the 20 kilometer where some  
13 guy is pumping water out of that well as fast as he  
14 can.

15 If that is not the focus of the staff,  
16 then I must say that I have missed the point, and I  
17 wonder what the regulations are. If that is the focus  
18 of the staff, then anything that reduces -- and any  
19 challenge to an assumption that would reduce that dose  
20 can be argued to be irrelevant.

21 And therefore you can approach -- if it is  
22 an issue resolution, you can approach it in another  
23 way.

24 CHAIRMAN WYMER: Yes, right.

25 DR. SHEWMON: I don't know whether DOE

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1 argues that, and I don't know whether the legal folks  
2 would allow that, but I would guess that is not a  
3 trivial consequence.

4 DR. MCCARTIN: I think the answer to your  
5 question is that if DOE has made a case that this is  
6 a conservative assumption, and you believe that the  
7 information that they presented supports that, you're  
8 right. The issue is closed.

9 CHAIRMAN WYMER: There is no reason for us  
10 to challenge it.

11 DR. MCCARTIN: In technetium, they are  
12 using a retardation of zero, and we don't care. I  
13 would argue that they are done.

14 CHAIRMAN WYMER: And from a very practical  
15 point of view, that is exactly correct. It does not  
16 satisfy scientifically, but it is okay.

17 DR. MCCARTIN: For us to make a decision  
18 based on that approach, we are confident that we can  
19 make a decision that will protect public health and  
20 safety.

21 DR. STEINDLER: Exactly.

22 DR. CRAGNOLINO: May I raise a point? In  
23 order to complete the response to that question, Dr.  
24 Steindler, we have adopted that criteria by inserting  
25 that DOE is conservative. There is no solid technical

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1 basis for the assumption that conservatism --

2 CHAIRMAN WYMER: That is the point.

3 DR. CRAGNOLINO: And that is in the debate  
4 currently for cladding, because DOE uses the criteria  
5 for cladding that they consider is conservative, at  
6 least the criteria of the solution of cladding by  
7 fluoride, but assuming that they are claiming more,  
8 and claiming that localized corrosion of cladding is  
9 not possible in their package.

10 They assume let's use fluoride as a  
11 surrogate, but the claim that that is conservative  
12 because it is an assumption of localized corrosion due  
13 to fluoride. But it is essentially controlled by the  
14 ability of fluoride, and that is contradictory.

15 DR. STEINDLER: Well, really what you are  
16 doing is that you are challenging the conservative  
17 nature of the assumption. Fine. If you have some  
18 mechanism of doing that, that makes sense, and you  
19 have provided one particular case, say fine.

20 But if you don't have any reason to  
21 challenge that assumption, and whether or not the  
22 stuff actually runs down that flow path, or disperses  
23 and reduces its concentration, are the only two  
24 options that you have so far identified.

25 If somebody comes in out of the blue and

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1 says, hey, guys, that's dead wrong. There is an  
2 underground river that this stuff drops into and  
3 whistles down to the guy's well, now you have got an  
4 assumption, or a statement, or evidence that makes  
5 this non-conservative. A different ball game. That's  
6 all I guess I am saying.

7 DR. AHN: However, DOE agreed to analyze  
8 the established --

9 CHAIRMAN WYMER: The reason they agreed to  
10 it was because he followed it.

11 DR. AHN: That is one way of doing it.

12 CHAIRMAN WYMER: And what you wonder about  
13 is what hasn't somebody thought of. We have Gustavo  
14 in this area, but how about some of these other areas?

15 DR. CRAGNOLINO: I think this is a general  
16 problem that we have to confront.

17 DR. AHN: We have a list that has been  
18 identified containing the --

19 CHAIRMAN WYMER: Well, for example, the  
20 kind of figure that exemplifies the point of what  
21 happens with that is the effect of lead on Alloy 22,  
22 and granted that things are way out of reason, the  
23 conditions under which they ran these experiments, but  
24 it was something that wasn't thought of. It was lying  
25 out there.

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1 DR. AHN: The current DOE position is to  
2 reopen whenever we identify new things.

3 CHAIRMAN WYMER: I realize that, but it  
4 bothers me because we are drawing on a limited pool,  
5 with specific areas, and what are you going to do.

6 DR. MCCARTIN: One quick thing, because  
7 this gets to one of the things that you were saying  
8 about the transparency traceability, which is clearly  
9 a big issue for us also. The challenge to write this  
10 in a simple form is hard.

11 CHAIRMAN WYMER: It is a big challenge.

12 DR. MCCARTIN: And I don't know how much  
13 of the TSPA-SR you have read. I mean, it is a fairly  
14 thick document. And having read some of it, I think  
15 that DOE has done a very good job of trying to pull  
16 out and distill from all the AMRs that they reference  
17 what are the key ideas.

18 And in addition, in terms of what have  
19 they missed, I think they have given other evidence of  
20 why I should believe this approach, and why this  
21 approach is correct. They have cited other evidence  
22 from analogs and other information throughout there.  
23 And I have not read it cover-to-cover.

24 CHAIRMAN WYMER: I have not read it  
25 either, Jim.

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1 DR. MCCARTIN: Some areas may be better  
2 than others, but I guess for the committee it is  
3 useful to read that. But having said that, I would  
4 say that I have been doing nuclear waste for 20 years.  
5 It takes me a long time even to read 10 pages of it.

6 I have to really think about is being  
7 said. It is a slow process. That is a big damn  
8 document, and even for someone who is -- well, I have  
9 done nuclear waste as I said for a long time, and it  
10 is a difficult thing to read through.

11 And I don't know in terms of -- well, I  
12 think they have put a tremendous amount of effort in  
13 information there. But anyone who thinks they can  
14 read it quickly, I don't know if anyone would be able  
15 to do that.

16 And therein lies the challenge. I don't  
17 know if you can distill it more than that. I just  
18 don't know.

19 CHAIRMAN WYMER: Yes, that is the  
20 challenge.

21 DR. CLARKE: So this has the elements in  
22 the document that I was describing.

23 DR. MCCARTIN: It will be interesting to  
24 get different people's reactions, and I would say it  
25 will take 2 to 4 months before some has read it from

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1 cover to cover. Now here are my comments.

2 But tangentially I am impressed and  
3 relatively happy about what they have attempted to do.  
4 I am sure that there are areas where we have  
5 differences.

6 CHAIRMAN WYMER: Well, it sure looks  
7 formidable. I will tell you that.

8 DR. MCCARTIN: But there is a lot of good  
9 information that they have distilled.

10 DR. CLARKE: It looks a lot smaller.

11 DR. STEINDLER: Gustavo, did you have  
12 something else?

13 DR. CRAGNOLINO: Well, it was with respect  
14 to the comment that you made about the connection  
15 regarding led. And there was some discussion going on  
16 this morning regarding oxidation energy --

17 DR. SHEWMON: Going back to what the  
18 people from Nevada brought in, or Catholic University,  
19 you are saying that is a high activation energy  
20 process, and so below a hundred degrees C, or below 80  
21 degrees C, it would go an awful lot slower?

22 DR. CRAGNOLINO: We don't want to take  
23 this for granted at the present time without further  
24 examination, but this is the way that you bound.

25 DR. SHEWMON: Ray, let me change the

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1 subject completely if I can, but a general discussion.  
2 I have something that maybe you wrote. I don't know.

3 CHAIRMAN WYMER: What is it?

4 DR. SHEWMON: It is the chemical  
5 environment on the waste package. Anyway, it's here.  
6 And it says that relative humidity, and when relative  
7 humidity exceeds the critical concentration, 80  
8 percent, we consider that corrosion is going to occur  
9 on the waste package.

10 The last thing on the page says the  
11 composition of the water contacting the waste package  
12 will not change significantly because of chemical  
13 interaction with it.

14 CHAIRMAN WYMER: That is a DOE statement.

15 DR. SHEWMON: Fine. But that is what  
16 offends me, is that the gas that the water all comes  
17 in through the vapor, and that keeps corroding, and  
18 the corroding nature producing ions, and there is no  
19 place for these to go.

20 But they can't change the composition of  
21 the liquid, which is silly. It has to saturate all  
22 the way. So it is conservative, but wrong.

23 CHAIRMAN WYMER: But it is silly, yes. Is  
24 that what I put in dark print there?

25 DR. SHEWMON: Yes.

1 CHAIRMAN WYMER: I bolded that.

2 DR. SHEWMON: I hadn't come across it, and  
3 maybe that is the way that the cookie crumbles in this  
4 world.

5 CHAIRMAN WYMER: Well, I don't think this  
6 world is scientifically any different than the world  
7 that you live in. But something has occurred to me,  
8 and I don't know whether it is real or not.

9 But there is a continual update of these  
10 documents, and there is a continual rewriting, and  
11 they dig out more information, to a large extent  
12 pushed by NRC for more supporting data and more  
13 documentation.

14 And they do this piece-wise, and I am not  
15 sure how well or how often everything has gone back to  
16 square one, and all these things are put together.

17 Now, this is an integrated thing, which  
18 itself will be a transitory document, because there  
19 will be a lot of stuff coming in after you write this  
20 document.

21 So, I am not sure whether after the pieces  
22 of the puzzle are joined together like this from one  
23 part of what happened to another part, and then they  
24 get dislodged maybe by some new information.

25 DR. CRAGNOLINO: Well, let me make a point

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1 since we are having a dialogue. An example was made  
2 about corrosion, and the critical factor controlling  
3 the life of a waste package containing Alloy 22  
4 doesn't have any date.

5 Therefore, they put together a bunch of  
6 experts like people that are in this room, and they  
7 offer their distribution of corrosion rate. So they  
8 have a group of people who have spread the rate of  
9 corrosion.

10 Now, we have to recognize that even though  
11 there are critical comments about the way that the  
12 corrosion rates are measured, at least they are  
13 reported and supported by current information.

14 It is our responsibility to be very  
15 objective in analyzing this, and this is what allows  
16 us to come to this agreement, because the issues are  
17 much better defined now. And we can focus on very  
18 certain narrow issues, but are they issues that allow  
19 the program to move forward.

20 If we resolve these issues, we are in a  
21 different stage, and we can say, well, this has a  
22 certain impact, and we can move forward. But I think  
23 that this is the type of situation that we have to  
24 recognize and we have to be astute and apt in  
25 identifying what are the problems, and not believing

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1 that we are much more clever than the other side of  
2 the fence.

3 DR. DAM: I am Bill Dam from the NRC  
4 Staff, and I wanted to respond to a few things that I  
5 heard.

6 CHAIRMAN WYMER: Have you got a list there  
7 about three pages long?

8 DR. DAM: Not too long, but in terms of  
9 requesting more documentation, and also your statement  
10 about colloids are a very important issue, I just  
11 wanted to highlight to the committee working group  
12 that in the information Jim handed out on page 7,  
13 there is an agreement that we came up with at DOE, and  
14 in number seven we said that they should provide  
15 sensitivity studies to test the importance of colloid  
16 transport parameters and models to performance for  
17 unsaturated and saturated zones.

18 Basically what happened at the Busted  
19 Butte test was that they weren't able to get their  
20 microspheres, which are the articles that they were  
21 using, they weren't able to move, and so now they  
22 don't have any data for looking at colloids in the  
23 natural unsaturated system.

24 So one of the things that we requested was  
25 that they look into doing a test such as that Alcove

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1 8/Niche 3, where they could inject microspheres, or  
2 other colloidal material. We gave them the option of  
3 maybe considering that.

4 We can't be prescriptive, but we just gave  
5 them ideas on how to proceed, and then you can see  
6 that we requested that information by this month.

7 DR. SHEWMON: Physically can you make  
8 polystyrene particles that are submicron?

9 DR. DAM: Yes, they are using them in  
10 different sizes.

11 CHAIRMAN WYMER: They are typically used  
12 to measure deficiency of filters.

13 DR. DAM: So the point that I was trying  
14 to make is that when we request more documentation,  
15 often times we are trying to request information that  
16 they maybe weren't planning to provide, or information  
17 that will get them to do an additional analysis that  
18 will be given to us in a future report.

19 And in this case it is going to be a  
20 letter report to us right away to tell us if they are  
21 going to be able to evaluate this technique.  
22 Secondly, they still have not given us a very good  
23 adequate justification for using the microspheres as  
24 analogs for colloids, and you will see our agreement  
25 number eight.

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1                   CHAIRMAN WYMER: I am not crazy about the  
2 idea either to tell you the truth.

3                   DR. DAM: And it is interesting, because  
4 that agreement, which deals with C-wells, which is in  
5 the fractured saturated zone, also applies to their  
6 current testing of alluvial tracers, which is in the  
7 alluvial material where they are using microspheres.

8                   So there is a lot there in those  
9 agreements that I just wanted to make the committee  
10 aware of, and going back to the statement that  
11 colloids are a very important issue, and it will be  
12 brought up by intervenors and other people, we are  
13 doing some things about that.

14                   We have had discussions, and we had a  
15 conference with the American Geophysical Union last  
16 spring, where we discussed tracers and brought in  
17 quite a few presenters to give talks about their work  
18 on that.

19                   And there is another session being  
20 considered and proposed for the fall of 2001  
21 specifically on colloids, and we are also getting in  
22 speakers to come in to the office and talk to us about  
23 bringing us up to speed from other sites, such as in  
24 Germany.

25                   So we are trying hard to get up to speed,

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1 both on the science and understanding the mechanisms,  
2 and understand DOE's modeling approach. It is  
3 interesting that we heard at the meeting that colloids  
4 are the greatest uncertainty in TSPA. So it is  
5 something that we are taking quite seriously.

6 DR. SHEWMON: I think you should.

7 CHAIRMAN WYMER: Yes.

8 DR. STEINDLER: Are they the greatest  
9 contributors?

10 CHAIRMAN WYMER: It is more of a  
11 perception thing than it is a scientific thing.

12 DR. STEINDLER: So if the uncertainty is  
13 never resolved, then it won't make all that much  
14 difference; is that what you are telling him?

15 CHAIRMAN WYMER: Except to the  
16 intervenors.

17 DR. STEINDLER: Except to the intervenors.  
18 Well, but I mean --

19 DR. DAM: Well, I think that is important  
20 to -- for instance, the Benum test that I mentioned,  
21 we need to pin down the mechanisms for the transport,  
22 and was it induced by the blast.

23 And the purpose of having these kinds of  
24 meetings, technical meetings, is to separate the  
25 perceptions from the science, and try to give what the

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1 hard facts are.

2 DR. MCCARTIN: But DOE has analyzed  
3 colloids, and it doesn't seem to be a significant  
4 contributor relative to other things, like technetium,  
5 and --

6 DR. STEINDLER: And so I guess my question  
7 continues to be if that is true, and I have no reason  
8 to believe it is not, why spend resources trying to  
9 fuss about colloids? It will take one great deal of  
10 effort to take that Nevada test site information and  
11 try either experimentally or by having another look at  
12 existing data to try and unravel how that plutonium  
13 traveled 1.3 kilometers in 30 years.

14 CHAIRMAN WYMER: And that is a valid  
15 question.

16 DR. STEINDLER: My question really is why  
17 is the staff pushing for that?

18 DR. MCCARTIN: Well, here is a case -- I  
19 mean, I don't know -- well, I will go with my memory,  
20 and that DOE is the one who brought this up more than  
21 we have. They brought up colloids as a problem that  
22 they were looking at.

23 We actually don't have it in our PA model.  
24 They brought it up and they put it in, and then they  
25 are giving this information as to how to represent it.

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1 Well, if you are going to bring it up, then --

2 CHAIRMAN WYMER: And you have to deal with  
3 it, yes.

4 DR. DAM: And then there is TSPA, and it  
5 does make a difference on it, in terms of dust.  
6 Plutonium, colloids, do have an impact on dust.

7 CHAIRMAN WYMER: Some, small.

8 DR. DAM: It all is very small.

9 CHAIRMAN WYMER: And it is perceptible.  
10 Why don't we turn our attention now just for the last  
11 little time here on defense-in-depth and multiple  
12 barriers issue.

13 DR. CAMPBELL: It's your turn to be on the  
14 hot sat, Tim.

15 CHAIRMAN WYMER: One of the sort of basic  
16 questions that comes to my mind -- and I don't expect  
17 anybody in this room to answer it, but how many  
18 barriers constitute defense-in-depth? What is  
19 expected? Are two enough?

20 DR. MCCARTIN: Absolutely.

21 CHAIRMAN WYMER: Well, there is the  
22 answer.

23 DR. STEINDLER: Okay. Anything else you  
24 want to know?

25 DR. MCCARTIN: I think basically that one

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1 is engineered and one is --

2 CHAIRMAN WYMER: One is natural  
3 environment.

4 DR. MCCARTIN: Yes, and I think the rule  
5 is very explicit in terms of multiple barriers.  
6 Defense-in-depth is really a broad philosophy for the  
7 agency.

8 CHAIRMAN WYMER: It is a bigger issue.

9 DR. MCCARTIN: And we would argue that  
10 Part 63 encompasses defense-in-depth. But in terms of  
11 multiple barriers, they are required to demonstrate  
12 that they have one engineered and one natural today.

13 Obviously drafted rules at the Commission  
14 could change that, but if you looked at the proposed  
15 rule, the intent was one natural and one engineering.  
16 If they do more, fine.

17 CHAIRMAN WYMER: Provided that both or  
18 those independently provide protection.

19 DR. MCCARTIN: Well, I am not sure what  
20 you mean by independently provides protection. They  
21 are not intended to be redundant.

22 CHAIRMAN WYMER: There is not much depth  
23 if either one taken alone doesn't meet the standard.

24 DR. MCCARTIN: We have never said that it  
25 is redundancy. There is nothing in the proposed rule

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1 that says you need to meet our regulation with only  
2 natural or only engineered.

3 The only statement made is that they both  
4 have to -- and I will caveat it and put in this word,  
5 is to have capability to either impede the movement of  
6 water, or radionuclides.

7 CHAIRMAN WYMER: Then that is an  
8 inadequate rule isn't it?

9 DR. MCCARTIN: Well, it depends on your  
10 perspective. I will go back and check, but I don't  
11 believe we got any questions to the effect or comments  
12 to the question that the barriers should be redundant.  
13 I could be wrong on that.

14 CHAIRMAN WYMER: Gee, somebody missed the  
15 boat.

16 DR. MCCARTIN: We did not offer that, and  
17 we tried to be fairly explicit that it was not  
18 intended to be redundant barriers. Now, you may  
19 disagree with that, and that's okay.

20 CHAIRMAN WYMER: Well, what do you think?

21 DR. MCCARTIN: I don't think redundancy is  
22 required. I support what the proposed rule requires.

23 CHAIRMAN WYMER: So if one is scratched  
24 and the other one doesn't meet the standard, it is  
25 still okay?

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1 DR. MCCARTIN: Well, if one barrier was  
2 removed, and --

3 CHAIRMAN WYMER: Or so diminished that it  
4 doesn't do any good.

5 DR. MCCARTIN: Well, they have to both act  
6 as barriers, okay? I mean, they have to have a  
7 natural and engineered barrier, and they both have to  
8 have the ability to act as that.

9 Because I will maintain that one of the  
10 things that -- well, if you had a 10,000 year waste  
11 package and a 10,000 year compliance period, that does  
12 not mean that you are relying a hundred percent on the  
13 waste package.

14 Yes, you are getting a zero dose, and you  
15 are getting a zero dose because nothing got out of the  
16 waste package. But the natural system still has come  
17 capability that didn't disappear because the waste  
18 package didn't fail. And it has to provide something.

19 DR. DAM: No one barrier can have undue  
20 reliance.

21 DR. MCCARTIN: But if failure of a barrier  
22 --

23 CHAIRMAN WYMER: And you only have two.

24 DR. MCCARTIN: -- in what I will call  
25 "unacceptable doses," you would have a problem. But

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1 unacceptable doses is not 25 in my mind.

2 CHAIRMAN WYMER: It is a hundred or 500,  
3 depending. That's the rule.

4 DR. MCCARTIN: No, the rule does not  
5 define what is an acceptable dose, and I think that is  
6 left at the discretion of the commission. Some people  
7 would say a rem is not an unacceptable dose.

8 But there is no specific number or time to  
9 local barriers.

10 DR. SHEWMON: Is the drip shield  
11 redundancy, or layers of defense on a waste package  
12 that is already good for 10,000 years?

13 DR. MCCARTIN: It sure looks like  
14 redundancy in terms of water.

15 DR. SHEWMON: I am just trying to get the  
16 idea whether redundancy is two identical pumps, when  
17 one will do it, and they don't have to be identical to  
18 be redundant?

19 DR. MCCARTIN: Well, we have not claimed  
20 that the repository has to be redundant, and in fact  
21 the preamble to the proposed rule did a pretty good  
22 job of -- there might have been a time when the  
23 commission set up sub-system requirements in the old  
24 rule, the waste package lifetime, and throw in travel  
25 time, and release.

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1           And there was a hope that these were  
2 independent barriers, and I think that in 1980, yes,  
3 that was a feeling. As time went on and you started  
4 analyzing the system, the repository system more, I  
5 think people realized that these really aren't  
6 independent barriers.

7           They aren't redundant, and there is --  
8 well, unlike, say like a reactor, where you could put  
9 in two pumps, and this one fails and this one will  
10 kick in, we have got a waste package that is dependent  
11 on the natural system.

12           The environment that it is in is certainly  
13 related to its corrosion, and the same thing with the  
14 drip shield. Now, the drip shield waste package, I  
15 guess you can sort of look at it and say there is a  
16 measure of redundancy between the two.

17           But the multiple barrier requirements is  
18 not a requirement for redundancy.

19           DR. SHEWMON: Okay. You have answered the  
20 question.

21           CHAIRMAN WYMER: Isn't EPA's position that  
22 you can't exceed 50 MR per year at the site boundary  
23 and not pore for water?

24           DR. MCCARTIN: That is their proposal. It  
25 is not final yet.

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1 CHAIRMAN WYMER: If that is true, then it  
2 is not up to the NRC to say, okay, it can be anything  
3 we decide it is.

4 DR. MCCARTIN: Well, no. In terms of  
5 compliance, and in terms of multiple barrier  
6 requirements, let's say that DOE did an analysis,  
7 where they -- right now under the proposed rule, you  
8 need to identify the barriers, and you need to  
9 describe their capability, and give the basis for  
10 their capability. That is the multiple barrier  
11 requirement.

12 Now, let's say that DOE does an analysis  
13 to give information to the commission as to how  
14 barriers perform and will neutralize the waste package  
15 and calculate the dose. Let's say it is 150  
16 milligrams when they do that.

17 Right now there is no quantitative  
18 requirement to say that it has to meet whatever the  
19 dose limit is, whether it be 15 or 25. Here is what  
20 happens when all the waste packages fail at T-zero.  
21 Is that good enough?

22 Right now I think it is a subjective  
23 decision for the Commission to look at, and that's  
24 what I meant. There is not necessarily a quantitative  
25 requirement in the proposed rule as to what -- well,

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1 there are no numerical goals for what constitutes a  
2 barrier.

3 We did get criticism on that and primarily  
4 Bob Buettner, who said how does DOE know they are  
5 done. You need to give them something so that they  
6 know that is a barrier.

7 CHAIRMAN WYMER: I think I agree with Bob.

8 MR. BRADBURY: Tim, my understanding is  
9 that the amount of the contribution of a barrier  
10 doesn't mean that you have to get it done at 25 or 15,  
11 but you have to show that the dose was reduced by a  
12 barrier.

13 So you are saying it is up to DOE for it  
14 to define whatever is defined as natural or barriers,  
15 and show me the relative contribution of that  
16 individual barrier, and then the TSPA, so me the  
17 overall contribution of the combined engineered and  
18 natural barriers keeping the dose below the dose  
19 limit, which is 15 or 25.

20 So, for instance, you can see the natural  
21 barrier alone knocks out all the short radionuclides.  
22 So 99 percent go just on natural barriers. So it is  
23 up to the engineered barriers to be designed to take  
24 care of that one percent.

25 In doing so, it has to be so robust that

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1 it also independently takes care of the other 99  
2 percent. But the contribution is still there from the  
3 natural barrier, number one, of knocking out the 99  
4 percent.

5 And even with the remaining one percent  
6 delay and all this other amplifying the benign  
7 environment to design again for the engineered  
8 barrier.

9 CHAIRMAN WYMER: Well, there seemed to be  
10 opportunities for quite a few barriers, chemical  
11 barriers, to back up all these other barriers. And  
12 there is a great depth of barriers possible.

13 DR. MCCARTIN: And DOE is required, I will  
14 maintain in the rules, to where they have to identify  
15 the barriers. In their performance assessment  
16 calculation, they have to identify the barriers that  
17 are contributing or have the potential to contribute  
18 to a decreasing dose.

19 They can't, for example, say, well, we  
20 will just count on the drip shield and our engineered,  
21 and the alluvium as our natural.

22 CHAIRMAN WYMER: Those are two.

23 DR. MCCARTIN: Those are two, but even  
24 though our waste package is lasting for 120,000 years,  
25 we are not going to count that. Well, the fact that

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1 the waste package lasts for 120,000 years is a  
2 significant barrier, and they have to identify that.

3 So anything in their PA calculation that  
4 has the potential to have a significant influence on  
5 performance is barrier and they have to identify it.  
6 Now, we don't require them and say, gee, we think you  
7 are going to get a lot of retardation in the invert,  
8 and include that.

9 But they don't have to, but if it is in  
10 their Ph calculations, they have to identify those  
11 things like that.

12 CHAIRMAN WYMER: So if they decided just  
13 not to put in the drip shield, then they would fail?

14 DR. MCCARTIN: Sure. It is what they are  
15 taking credit for in their PA calculation.

16 CHAIRMAN WYMER: Well, I can see why they  
17 don't want to get into these chemical factors much  
18 then.

19 DR. STEINDLER: I do have to ask the  
20 question reduce those from what? When somebody says  
21 reduce, you have got to show that it reduces the dose  
22 from what?

23 CHAIRMAN WYMER: From what it would be  
24 without it.

25 DR. STEINDLER: From what it would be

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1 without it, but if you are in a geologic disposal  
2 area, it is difficult to eliminate the geology. I  
3 mean, otherwise you are in the business of saying,  
4 well, my waste package is sitting on top of the  
5 ground. Things get pretty silly is what I guess I'm  
6 saying.

7 DR. MCCARTIN: Well, we don't require that  
8 type of calculation in the proposed rule, and it is  
9 what is the capability and what is the basis. So I  
10 would maintain for the geology that you could go to  
11 the alluvium and look at Kds.

12 DR. STEINDLER: Then let me ask the  
13 question differently, and I couldn't remember what he  
14 answer is if there was an answer to it. Do you  
15 require independence?

16 DR. MCCARTIN: No.

17 DR. STEINDLER: You do not require  
18 independence?

19 DR. MCCARTIN: No. In fact, we said the  
20 barriers are not truly independent.

21 DR. STEINDLER: They don't have to be  
22 independent.

23 DR. MCCARTIN: Well, we don't think they  
24 are. They can't be, because, for example, the waste  
25 package is totally dependent on the environment that

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1 the natural system creates for it.

2 DR. STEINDLER: But that is a very broad  
3 description. The waste package is pretty independent  
4 from the Calico Hills, unless you believe that water  
5 is going to rise.

6 DR. MCCARTIN: Yes.

7 DR. STEINDLER: So if you call the Calico  
8 Hills one of a series of defense-in-depth barriers,  
9 those are independent.

10 DR. MCCARTIN: Yes, but --

11 DR. STEINDLER: The Commission has  
12 required in the area of functional criticality in the  
13 case of at least facilities in the field cycle, three  
14 independent separate events.

15 So the whole notion of nested safety is a  
16 long term notion in the Commission's general  
17 philosophy, unless they have changed them in the last  
18 few years, and I haven't paid attention.

19 I would be startled if independence in  
20 that sense is not a requirement. Otherwise, it  
21 doesn't make a whole lot of sense frankly to require  
22 a whole series of defense-in-depth, a set of nested  
23 barriers.

24 If I can knock them out with one event,  
25 what have I got? I mean, the intervenors will cut you

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1 to ribbons and should I think.

2 DR. MCCARTIN: Well, we did not try to  
3 prescribe any type of independence, redundancy, or  
4 anything to the multiple barriers other than looking  
5 at engineered and natural, and just describe for us  
6 the barriers that you have in your calculation.

7 DR. STEINDLER: I can remember when Mel  
8 Napp gave us a lecture about a committee, and gave us  
9 a lecture about the role of barriers. Basically, his  
10 argument was you have got to have them, because who  
11 knows, there may be something that goes wrong with one  
12 that you haven't thought of.

13 And so our comeback was that we're smart,  
14 and so is the staff, and they have thought of  
15 everything. He didn't buy that. So in that sense  
16 independence is a requirement if you haven't thought  
17 of it. But that is an observation and I am not trying  
18 to argue the issue one way or the other.

19 DR. MCCARTIN: I think the closest that we  
20 have come to it is in the subpart on technical  
21 criteria, and we talk of that you are looking at  
22 multiple barriers to provide a measure of resilience  
23 to the repository.

24 DR. STEINDLER: Yes.

25 DR. MCCARTIN: But there is no explicit

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1 statement that they have to be independent.

2 DR. STEINDLER: Do you use the term of  
3 defense-in-depth?

4 DR. MCCARTIN: No.

5 DR. STEINDLER: Good, because there is a  
6 big argument about whether that makes any sense at  
7 all. It is a thousand year ground water travel time  
8 turned out to be kind of laughable when you are  
9 talking about what travels.

10 DR. MCCARTIN: Yes. Then we had a 300 to  
11 a thousand year waste package lifetime, and if you  
12 look at it now --

13 DR. STEINDLER: Well, there was a lot of  
14 faith involved that geology in fact would do something  
15 for you. And geology doesn't do quite as much for you  
16 as you thought.

17 CHAIRMAN WYMER: And defense-in-depth  
18 incorporates non-scientific things, too, if you really  
19 explore what it means, you know. It could be part of  
20 your organizational structure and the way that you  
21 have got things set up.

22 DR. STEINDLER: Well, that wasn't allowed  
23 I don't think. Defense-in-depth generally involved  
24 technology, or technological criteria more than  
25 anything else.

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1 DR. MCCARTIN: Well, I think since the  
2 white paper came out on defense-in-depth from the  
3 Commissioner, I think we have tried to look at Part 63  
4 and how there are the elements of defense-in-depth,  
5 and I think part of it, for example, from a mitigation  
6 standpoint, there is a requirement that they have to  
7 do post-closure monitoring.

8 DR. STEINDLER: Yes.

9 DR. MCCARTIN: And part of that is a  
10 mitigation measure, and that you are going to put up  
11 a system for perpetual care and monitoring of the site  
12 by DOE and can we rely on it? No. But there are  
13 certain things like that that have an element of the  
14 broader context.

15 DR. STEINDLER: It is my personal view  
16 that the post-closure monitoring order on 300 to a  
17 thousand year life package, and a thousand year ground  
18 water travel time, in terms of efficacy, and of giving  
19 me warm and fuzzy feelings.

20 CHAIRMAN WYMER: Again, it is a question  
21 of did you anticipate everything.

22 DR. MCCARTIN: Of course, we can embrace  
23 it.

24 CHAIRMAN WYMER: I think we are getting to  
25 the end of the string here. Tomorrow morning we will

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1 begin again at 8:30, and tomorrow morning will be  
2 largely a bull session. We are just going to kick  
3 things around, and probably try to decide on what the  
4 format of the content of a letter might be, and what  
5 kinds of things we should include.

6 We will not discuss specifically what we  
7 are going to include, but exactly how we should  
8 structure the letter, and what things we should cover.

9 DR. CAMPBELL: We do have some discussion,  
10 a couple of facts. I don't intend to really go into  
11 TSPA, because as some of you have seen, this is a lot.

12 And in fact what I have kind of pulled out  
13 and talked about today are really things that I have  
14 been pulling out of TSPA and maybe going into AMR. I  
15 think we need to talk about a couple of effects.

16 One of the things that came up earlier was  
17 how all of this discussion relates to the issue  
18 resolution process and I sent them to you guys, but  
19 you probably didn't drag them with you, and that is  
20 the summary highlights of the three main tech  
21 exchanges that impact what we are talking about.

22 One is the container life and source term,  
23 and I am going to leave these with you guys just to  
24 help you, Evolution of the Near-Field Environment, and  
25 Rad Transport.

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1                   What these do is to at least give you --  
2                   you know, take a look at them and see if there is --  
3                   well, given your particular concerns or issues that,  
4                   one, has it been addressed by the staff, or two,  
5                   hasn't it been. We are adjourned.

6                   (Whereupon, the meeting was adjourned at  
7                   4:39 p.m., to reconvene at 8:30 a.m., on Thursday,  
8                   February 22, 2001.)

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**CERTIFICATE**

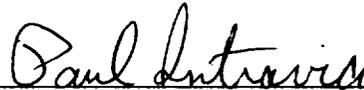
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Name of Proceeding: ACNW Audit Review

Docket Number: (not applicable)

Location: Rockville, Maryland

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



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Paul Intravia  
Official Reporter  
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