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WASTE PACKAGE WORKSHOP

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1 case, Digby has volunteered to perhaps defer discussion of
2 the C-22 over graphite. The concept rather than graphite is
3 something that would be essentially more thermodynamically
4 stable, some type of material, and we'll want to think about
5 what perhaps some of the other materials might be. Dan is
6 not going to give up on it. Maybe, he will give up on rod
7 consolidation, but wants to talk about designs that
8 potentially would involve additional shielding and
9 ventilation issues. He wants to be sure from the standpoint
10 of a consideration of those issues for research needs that
11 they don't get lost in the shuffle.

12 So, in our discussion, one of the issues, I think,
13 related to shielding has to do with maybe more of a policy of
14 advantages of shielding and whether or not, in fact, the
15 ability to be able to have workers go into the drifts and
16 make inspections or actually make repairs during some period
17 of time is of value and that sort of policy is not something
18 that's easily made by the members of this Panel.

19 Are there any other issues on shielding that you
20 think we should get out on the table, Dan, short of getting
21 that policy statement on its advantages. Or maybe you'd like
22 to make that case?

23 BULLEN: Not necessarily make the case because when we
24 step over policy bounds, we always get in big trouble, but
25 they never seem to--

1 COPPERSMITH: I know you stay well within the bounds--

2 BULLEN: It never seems to stop me, but--

3 COPPERSMITH: Go ahead, John?

4 KESSLER: I was going to make a relevant comment about
5 shielding. To me, the issue is always, well, you can walk up
6 and down and look at things. And, to me, for talking, trying
7 to couch things in terms of research needs, it would be
8 awfully nice to have a clear description of what it is we're
9 supposed to be looking at or that the project would want to
10 look at. What are the benefits in terms of true performance
11 confirmation that one gets by looking at particular things?
12 And then, that might help then elucidate whether shielding is
13 or isn't needed in the long run.

14 BULLEN: Yeah, with the shielding issue, the one thing
15 that I'm looking at is the confirmatory testing phase of
16 tunnels above and boreholes that are basically going to have
17 monitoring devices for temperature, relative humidity, and
18 the like. And, actually, shielding ties in with the
19 ventilation and that ventilation, if you talk about that
20 beforehand, what we're looking at is we're looking at the
21 ability to not disturb the near-field environment which could
22 immediately be put into the parking lot here because it's
23 beyond the scope of waste package. But, without disturbing
24 the near-field environment much, basically keeping the
25 temperature low so we don't mobilize as much water, we don't

1 have a dynamic mountain where basically I've got diurnal and
2 barometric pumping and pressure changes that are going to
3 move large quantities of water around, raining on various
4 waste packages as a function of time that we may not know.

5 The limited impact of a ventilated repository is
6 one benefit. The second benefit associated with the
7 shielding is that there will be a case where I'm going to
8 take a look at what effect I have and the effects that I have
9 are going to be monitored by not only monitoring packages,
10 but monitoring tunnel stability, monitoring movement of
11 water, monitoring temperature. All of those things are going
12 to have to be done either remotely, if it's a hot, closed off
13 environment, or that monitoring can be done in tunnel with
14 sensors replaced by someone that has access to a radioactive
15 materials area, not necessarily 24 hours a day, but you know,
16 if you go into a 200mr per hour field, that's a reasonable
17 thing to do is a radiation worker.

18 So, the types of things that I'm looking at are
19 associated with tunnel stability, effects of the near-field
20 environment, movement of water, temperature, and those types
21 of access--well, and the access for tunnel repair if that's
22 what we're really concerned about.

23 Now, ventilation has another salient benefit in
24 that if we do ventilate, then I don't have to worry about the
25 radiative heat transfer distances and I can make my tunnel

1 diameters smaller. So, if I have a 200 degree C rockwall
2 temperature concern, in a ventilated environment, I don't
3 have to worry about the radiation being the heat transfer
4 mechanism; I have to worry about basically gas flow. Now,
5 Tom Doering noted that we'd probably have to have gale force
6 winds coming through there and that may or may not be the
7 case, but those kinds of research issues are the things that
8 I'd like to have addressed in a manner that would tell me
9 whether or not it's worthwhile to ventilate or I should just
10 go ahead and say I've got to have confirmatory tests from
11 tunnels above the repository and take a look at water motion
12 from well beyond the cave.

13 The concern that I have is that we're looking about
14 hydrogeologic uncertainty and that's the whole reason that
15 the Board said we should do an east-west crossing is that we
16 want to take a look at what's coming. I mean, my simplistic
17 view is what's dripping from the ceiling and when, and that
18 may not occur when I have a ventilated repository because I
19 want to be drying it out. So, I may not have an opportunity
20 to see that. But, in a heated repository, I'm pretty sure
21 I'm going to have that.

22 MACDONALD: I think if one buys into ventilation on a
23 continuous basis, you have to ask the question whether you
24 want to put the canisters into the tunnel, at all. Why not
25 just put them in dry storage facilities until the temperature

1 drops?

2 BULLEN: You really do want to get us in a policy bind
3 here. That's not an option that as a technical reviewer, we
4 can look at. We're taking a look at we have to put something
5 in the mountain, and to do that, what's the best approach?
6 On the record, I could even say I agree with you, Digby, but
7 we're looking at a monitored geologic disposal site. Is
8 that what MGR--oh, MGR, monitored geologic repository; thank
9 you, Dr. Stahl. So, that's the issue, Digby.

10 PAYER: But, one of the things that I think has to be
11 analyzed carefully is the--and there's pages out of the
12 chemical process industry where corrosion sensors and probes
13 are becoming quite widely used and applied. It's always nice
14 to know these things, but the folks in the industry look very
15 carefully before they drill a hole through a pressure vessel
16 and put that monitor in there. What you certainly don't want
17 to do is reduce the reliability and increase the potential
18 for hazard by adding monitoring devices. So, while
19 monitoring makes some people at first glance feel warm and
20 fuzzy, if it increases the complexity and, in fact, brings
21 more potential damaging processes into play, then I think it
22 has to be looked at very carefully. That's what makes
23 Digby's suggestion about a way of perhaps having a pre-
24 storage cooling and then a final storage something that, you
25 know, borders on policy; then, so be it. I think the policy

1 ought to be looked at.

2 SHOESMITH: Isn't a repository open for 300 years and
3 inspectable really just a dry storage facility anyway,
4 whatever way you--

5 PAYER: Yes, but it's a very complicated dry storage.
6 Is that the best place, you know, with large--it puts a
7 tremendous design and function burden now on the drift walls
8 and you're going to have to make those significantly
9 differently than if they just had to maintain access to
10 emplace the waste packages. I think it's a big deal.

11 BULLEN: I think our executive director sent me a subtle
12 message when he parked long-term storage over there in the
13 parking lot. So, I think that means that we should probably
14 preclude any discussion on this and maybe that drives
15 ventilation also and those issues. But, to be honest, I just
16 want it on the record that shielding and ventilation issues
17 and I'll also add rod consolidation for criticality concerns,
18 but I'd like those things, you know, stated in the workshop
19 and we can decide not to address them any more. I notice
20 that we have 12 minutes left to discuss design alternatives.
21 So, I'll stop now. Is that all right, Kevin?

22 COPPERSMITH: That's fine. I think the other thing
23 that, Joe, you might want to mention that you brought up
24 dealt with the possibility of a smaller canister and then the
25 associated implication perhaps of that.

1 PAYER: The thought process goes along the lines that I
2 mentioned in our earlier session this morning that perhaps a
3 consensus wasn't reached yesterday, but there was certainly a
4 lot of agreement from several corners that, from a corrosion
5 standpoint, resistance to drips and water films and the
6 ambient nominal water chemistry at the mountain and likely
7 modulation of that environment by crevices and rock and such,
8 that C-22 and titanium are certainly at the top of the list
9 of corrosion resistant materials in that kind of environment.
10 Even with those environments, we have to do a good job of
11 identifying what the environment is because they have
12 potential of corrosion in extreme environments.

13 Having said that, one of the things we wrestled
14 with yesterday was the mechanical requirements of the
15 canister and how that keeps pushing us back toward carbon
16 steel which we can accept, but it brings along some corrosion
17 difficulties with it not only for the carbon steel, but also
18 for the outer pack or for the corrosion resistant metal. So,
19 the thought is can we relax those mechanical constraints by
20 making the canister significantly smaller? So, rather than a
21 couple meters in diameter or whatever, more like a meter in
22 diameter. They'd weigh less, they'd be easier to handle,
23 there would be more of them, certainly. So, you know, we're
24 talking about tradeoffs here, but if you do that with a two
25 centimeter thick C-22, you've still got a significant

1 mechanical integrity and ductility and so forth. And, what
2 are the benefits of that? And then, you can start moving
3 them around and putting them in places. If the rockfall
4 still is a major issue and to overcome that, then you can go
5 to backfill or put them in smaller drifts and so forth. So,
6 I think it's a serious design option that ought to be
7 seriously considered and the tradeoff done. And, it would be
8 the things we've listed here probably the most significant
9 difference in design of what the repository would look like
10 compared to the others where we're just changing the
11 materials and the layers and what goes on what.

12 COPPERSMITH: I think the spirit here is to evaluate
13 these, would be to identify perhaps the research needs
14 associated with the evaluation of those design options.

15 What about backfill?

16 PAYER: Well, I think the effect of crushed top rock
17 deposits on the corrosion behavior of all these metals, the
18 steel, titanium, C-22, is something that needs to be
19 considered anyway and this option would make sure that--I
20 mean, that would be the starting point. It would start with
21 consolidated tuff around them or whatever. So, I think the
22 research need would be to certainly include that in the
23 situation.

24 COPPERSMITH: So, these are an engineered backfill or a
25 natural backfill eventually?

1 BULLEN: Regardless of whatever design we pick, we're
2 going to have backfill eventually. So, you might as well do
3 the research and decide how long the materials are going to
4 last with the crushed tuff either put in by us or put in by
5 nature. So, you're going to have to do that research anyway.

6 SAGÜÉS: By that, you mean, the tunnel--

7 BULLEN: Yeah, natural consolidation if you want to call
8 it that. But, yeah.

9 COPPERSMITH: I guess, that's a lot cheaper, isn't it?

10 BULLEN: Just wait; patience.

11 COPPERSMITH: Okay. Anything else on designs?

12 MACDONALD: Let me just make a comment on the design. I
13 think we would be wise to engineer the design such that we
14 put a minimum burden on future generations. What really
15 concerns me about this present plan is it's an awfully
16 complex plan. It requires future generations to do things
17 for essentially obligations that we have made on their
18 behalf, and I notice it's getting into policy. I'll do it.
19 You know, if you look throughout history, there's hardly a
20 century gone by without some major social calamity. I think
21 we just have to count on social calamities in the future.
22 It's just 250 years ago that this country had a major social
23 calamity, and there's no guarantee that we won't have another
24 one in 100 years from now. I just think it's unwise for us
25 to make these obligations on future generations. So, we

1 should engineer a system that is essentially "bury and
2 forget".

3 KESSLER: I'm not sure that there's anything particular
4 about the fact that they're talking about 300 years now that
5 wouldn't allow them at any time to close it off right then
6 and there.

7 MACDONALD: Well, ventilation, for example, requires
8 some active machinery that has to be kept going. It requires
9 a--

10 KESSLER: Sure, sure. In the case of ventilation, yes,
11 again I understand that. Or backfill seem to be an
12 absolutely essential part of the design. Issues like that, I
13 can understand.

14 SHOESMITH: I don't wish to prolong a policy discussion.
15 I think we should be talking about these other things, but
16 that, of course, was everybody else's idea. You know, shut
17 it up, walk away, forget it, it's nobody's problem. You
18 know, the problem then solved. But, all public hearings that
19 we held said that they wanted retrievability and monitoring.
20 That was the two major public concerns. So, we may wish to
21 do that; most people didn't wish us to do that.

22 PAYER: I think the issue, though, is what they mean by
23 retrievability and monitoring. You can certainly have in a
24 passive repository that didn't require or have plans for
25 going down and being able to clean up rockfalls and polish up

1 drift walls and pack the canisters, you can still have
2 monitoring and retrievability. So, I don't think you have to
3 abandon those two. You could still have sensors put in place
4 that would monitor, as we said, the temperature so we would
5 better understand the mountain through its history. You
6 could still have radionuclide sensors that would sense if
7 there was any early release or how much and that type of
8 thing. So, I don't think it's an either/or.

9 But, I agree with Digby; the more that you build
10 into this complexity and the need for people and/or machines
11 to go down there on a periodic basis, it just seems to me to
12 be counter intuitive as far as the likelihood. John, as you
13 mentioned, well, they always would have the option of going
14 in and shutting it up, but in time of some whatever the
15 distress is, socioeconomic, that may not be the highest
16 priority or it may not be where you want to put your
17 resources in on time. So, it seems to me a passive
18 repository that meets all these other standards is a
19 desirable goal.

20 KESSLER: I guess that just makes me want to reiterate
21 my point about a clear statement on why it is we're going in
22 and monitoring, what it is we're going to monitor for, how
23 that's really--whatever it is you can monitor for, whether it
24 makes a hill of beans worth of difference for knowing long-
25 term performance.

1 SPEAKER: It's a research need.

2 KESSLER: Yes, it's a definite research need, yes, to
3 define that in terms of not only what you monitor for, how
4 you do it, what available techniques there are, etcetera.
5 Then, you'll start knowing whether you need ventilation and
6 shielding and all these other things.

7 BULLEN: At the risk of even stepping farther over the
8 policy bounds--

9 KESSLER: That wasn't policy bounds.

10 BULLEN: As we do the monitoring and as you find out
11 things, the question is what are you going to do about it?
12 If you monitor radionuclide release, are you going to go
13 remediate or not?

14 KESSLER: Exactly.

15 BULLEN: That's a decision as to why?

16 KESSLER: Exactly.

17 BULLEN: --rockfall, does that mean you have to do
18 something or not?

19 KESSLER: Right.

20 BULLEN: So, this is a real tough policy decision
21 because we might find out something that it's not going to
22 make any difference whether we do it or not. So, why would
23 we want to monitor? Now, I just talked in the counter
24 intuitive to why we'd shield and ventilate, but it's the key
25 question that you'd have to take a look at and it is a policy

1 decision. What are you going to do? Do you bury it and walk
2 away as Digby mentioned?

3 KESSLER: I don't know if there's anyone here who has
4 been--

5 BULLEN: If you look at all we've talked about in the
6 waste package design in the past two days, nobody expects in
7 the first 100 years to have openly leaking containers. If we
8 did, we're pretty bad designers. So, what do you expect to
9 see? During our lifetime, probably nothing; and, during the
10 300 years, most likely, nothing. And so, you want to confirm
11 nothing, I understand that; but you don't want to spend a lot
12 of money doing it.

13 STREICHER: What would happen if there were only one
14 failure to your ventilation? Would you have to stop
15 ventilating?

16 COPPERSMITH: It depends on the ventilation system,
17 whether or not it has the redundancies built into it, again
18 complexity--

19 BULLEN: My guess is it doesn't always have to be active
20 ventilation. There are a number of designs for passive that
21 --you know, an active ventilation would allow access and a
22 passive ventilation would keep the temperature at a limit and
23 those are the kinds of things that haven't been completely
24 analyzed. EPRI did a ventilation study that had a number of
25 different options associated with it. I don't know how

1 detailed that was.

2 KESSLER: It wasn't detailed and we made a lot of
3 simplifying assumptions in there. Looked at one cubic meter
4 per second in 10 to see how much difference there was and we
5 found that even one was a significant benefit.

6 BULLEN: It makes a big improvement over .1. And, the
7 .1 is the leakage by the doors right now, as I understand.

8 KESSLER: We compared it to zero.

9 BULLEN: Oh, to zero, okay.

10 KESSLER: Zero to .1.

11 BULLEN: Okay. In answer to your question, a
12 ventilation failure would have an impact, but it may not have
13 the catastrophic impact that one might expect. I mean, it's
14 obviously going to be better than having completely closed up
15 drifts, no matter what you have, with some passive
16 capabilities, as well as active.

17 STREICHER: Yeah, well, I didn't really mean a
18 ventilation failure. I meant if there were a radioactive
19 material leaking just from one container, would that make it
20 impossible to pull that air out through that system?

21 BULLEN: Oh, no, I don't think so because all
22 ventilation as we're doing construction is going to have HEPA
23 filter characteristics. I mean, no, I don't think that's a--
24 it's a complexity issue, but it's not beyond the scope of
25 what you'd naturally do for ventilation in an operating

1 facility anyway.

2 COPPERSMITH: At the risk of pulling it completely out
3 of the parking lot, let's say this is a research need to look
4 into the pros and cons of ventilation.

5 KESSLER: Yeah, I was going to say it just seems like
6 it's pretty clear from this discussion that performance
7 confirmation and what you're going to do with it or not do
8 with it could have a major impact on what you've got for
9 design options. The sooner that performance confirmation is
10 well-defined, the more buy-in one might get on any particular
11 design option at that point.

12 COPPERSMITH: Any other discussion on designs?

13 (No response.)

14 COPPERSMITH: We could come up with new ones as we go
15 along, but I'd like to move on to discussion of research
16 needs. There is a point here where Joe Payer is going to be
17 done with the viewgraph he's working on which deals with a
18 tieback to some of the environmental scenarios that we had
19 yesterday, but I'll let him finish that.

20 In the meantime, what we thought we would do here
21 rather than go through all these designs again is to focus in
22 on a few and see if they, in fact, handle our research needs.

23 We're thinking of looking at Option Zero, 2 Prime, 4--

24 BULLEN: Do you want to cross off nodular and cross off
25 iron and put steel because it's not nodular steel, either.

1 COPPERSMITH: Yeah. And, potentially 6.

2 KESSLER: We're not going to address 3 which was the
3 inside-out design?

4 COPPERSMITH: Yes. What did I miss?

5 BULLEN: The research needs for 4 are not much different
6 then the research needs for 3.

7 COPPERSMITH: Okay. So, that's why we decided that.
8 Okay. That's what we think right now, but there may be some
9 other ideas as we go along.

10 So, let's think about #1, the carbon steel over C-
11 22, a novel idea. I think others have thought of it before.
12 What research needs do we see that would be important in
13 analyzing this design or dealing with the pros and
14 particularly the cons of that design? Digby?

15 MACDONALD: I'll come back to the fast growth of
16 magnetite; I think is an essential thing that has to be
17 looked at.

18 COPPERSMITH: How would it be addressed? What ideas
19 would you have?

20 MACDONALD: Experimentally. I mean, it would--just see
21 what conditions can be generated by water dripping down onto
22 the top of a heated surface. That that can generate the
23 conditions that lead to the fast growth of magnetite.
24 Because if fast growth of magnetite occurs, you're not going
25 to have carbon steel for very long.

1 COPPERSMITH: Do you see these experiments as being a
2 long-term, large resource--

3 MACDONALD: On the conditions of a nuclear steam
4 generator which, of course, is somewhat different than what
5 we're talking about here, you get corrosion rates that are,
6 you know, centimeters to meters per year. It's not going to
7 take very long to decide that issue, I do not believe. But,
8 you know, if we're relying upon carbon steel for structural
9 integrity and C-22 for corrosion integrity, then I would
10 argue that the C-22 should be on the outside and the carbon
11 steel should be on the inside.

12 COPPERSMITH: But, how does that--I mean, going back to
13 this issue, I mean--

14 MACDONALD: You know, if you get rid of your carbon
15 steel by putting it on the outside and allowing it to
16 corrode--

17 COPPERSMITH: We said yesterday there is a certain
18 element of corrosion resistance to the carbon steel outer.
19 Given environmental scenario #1, for example, there is a
20 period of dry oxidation--

21 MACDONALD: Not comparable to C-22 because you would
22 have much thicker carbon steel and it may become a cost
23 issue. Matter of fact, it will become a cost issue. But, it
24 seems to me that the primary role of the carbon steel is
25 structural integrity, unless I've missed something.

1 STREICHER: And, radiolysis.

2 MACDONALD: Yeah, right, radiolysis.

3 SHOESMITH: I agree with Digby that this fast carbon
4 steel corrosion process is something that needs looking at.
5 I think the mechanism will be a little bit different to what
6 the end reactor one is because I don't necessarily think
7 you'll stay at magnetite. In the end reactor situation, it's
8 the porosity and acidity in pores which allows it to grow on
9 the outside. So, it never, ever becomes protected. Here, I
10 think the bigger danger is that you'll grow a layer, dry and
11 crack it, then you'll effectively expose the underlying
12 layer, and then you'll grow another one. The film will never
13 actually be protected. But, it's a similar scenario. It's
14 says this is a fast pathway through carbon steel. I think
15 this rapid corrosion followed by spalling is potentially a
16 big effect on carbon steel. I think Gdowski has experiments
17 of that nature underway if somebody would confirm that.

18 PAYER: I would suggest that when carbon steel is wet
19 that with just the straight general corrosion rates that
20 Gdowski and others have already measured that the life of the
21 carbon steel is so short that it's already not contributing a
22 lot once it's wet. This would just be an even less
23 contribution, but I think the steel is going to go pretty
24 quickly when it's wet anyway.

25 MACDONALD: You've lost your structural integrity.

1 PAYER: That's right. So, I mean, I think there's other
2 things that are taking carbon steel out that we understand
3 and we know are going to exist under realistic conditions
4 there. So, from that standpoint, I would give this a less
5 priority in the research needs. I think it's a real
6 phenomena and it's a real curiosity, but there's already
7 things that are making the life of carbon steel quite short.

8 COPPERSMITH: What about the spalling issue? Is it
9 worth looking into that?

10 PAYER: I put it in the same sort of category. It's the
11 same with the pitting of steel which is s concern. The lives
12 are already quite short, it seems to me, when it's wet. If
13 it ain't wet, then it's okay.

14 MACDONALD: Yeah, but the model predictions are
15 suggesting a few thousand years. Yet, all I hear on the
16 table is ten to 100 years.

17 COPPERSMITH: Well, correct me if I'm wrong. I think,
18 Joe was saying once it's wet.

19 SHOESMITH: Yeah, it's 10 to 100 years after it's wet.

20 COPPERSMITH: Right. So, environmental scenario 1,
21 there's a long period before--presumably, before it's wet.
22 So, that's what the model prediction is, I think, taking
23 advantage of that.

24 SHOESMITH: I still think 10 to 100 years is a special
25 scenario for the frequent drip on the same site. I don't

1 think this is a general phenomenon for carbon steel. A drip
2 at a very regular interval on the same site for many, many
3 years, carbon steel is out. So, you're back to trying to
4 determine if the carbon steel is viable, and you're back to
5 trying to determine whether that scenario is a frequent event
6 or not.

7 COPPERSMITH: I think maybe a theme between now and 3:30
8 is going to be additional research needs associated with the
9 location frequency, chemical content of drips.

10 SHOESMITH: And then, there is a question. Is it worth
11 it?

12 MACDONALD: I personally think we have to assume drips.
13 Okay? We have to assume that the drips will appear on the
14 same location. I don't see how we can rule that out.

15 COPPERSMITH: Well, maybe this group needs to assume
16 that, but there's a group of thermal hydrologists that don't
17 necessarily need to assume that; their models and their
18 studies and they're doing active research on that. So, maybe
19 for this group, it's worthwhile to consider that assumption
20 to be in place. In fact, I think that was one of your
21 assumptions yesterday is to go ahead and assume dripping
22 conditions.

23 MACDONALD: Right. I think it's a very reasonable
24 assumption.

25 COPPERSMITH: Yeah, I don't argue that.

1 PARIZEK: There are geological controls that are there
2 that will guide the water that will stay there. Fractures
3 will be there, wherever they're going to be, and that will
4 guide the water sources into the chemistry.

5 COPPERSMITH: Mike, you had a comment?

6 STREICHER: Well, if the carbon steel--the structural
7 support of that is gone because of corrosion, will the
8 remaining C-22 provide enough physical support for what is
9 needed in the way of rock and whatnot that has been talked
10 about?

11 COPPERSMITH: So, is this a research need in your mind?

12 STREICHER: Not necessarily. We can tell what the
13 structural support of C-22 will be in the thicknesses that
14 have been provided here.

15 COPPERSMITH: Okay. So, more of a calculation, right?

16 STREICHER: We don't like the carbon steel out there
17 because of the corrosion environment that's going to be
18 created for the C-22. But, we haven't discussed very much
19 what the residual physical strength is that is left when the
20 carbon steel is gone.

21 COPPERSMITH: Have those calculations been done? It
22 seems to me that would be a very obvious calculation. Tom?

23 DOERING: Would you ask the question again?

24 COPPERSMITH: The question, have calculations been done
25 on the chemical integrity of a package where basically all

1 the carbon steel has been corroded away? Does a two
2 centimeter thick C-22 canister have much resistance to things
3 like rockfall and so on?

4 DOERING: Well, two years ago, we actually looked at
5 Alloy 625 at that time and it appears similar to the
6 mechanical strength of C-22. And, what we did was just thin
7 the materials at that time, and understanding that most of
8 the rockfalls would have to come down by the time frames that
9 we're looking at, then the two centimeters at that time was
10 deemed to be sufficient for the rockfalls that the subsurface
11 geologists had determined for us to come in. Those
12 calculations have been done and have been documented in our
13 system. So, it's something we can recover quickly.

14 KESSLER: Perhaps, Tom may be the wrong person to ask,
15 but we keep talking about this issue as to when the carbon
16 steel disappears versus when rockfall is likely to be of a
17 major importance. My understanding is that rockfall is going
18 to happen early rather than later during the hottest part of
19 the cycle. At that point, it sounds like we're suggesting
20 that perhaps there's going to be more carbon steel hanging
21 around and so we'll have more structural integrity during the
22 dominant part of the rockfall, barring, of course, long-term
23 seismic activity.

24 DOERING: That is our understanding, too.

25 KESSLER: Okay.

1 COPPERSMITH: Yeah, the calculations I've seen would
2 imply that the thermal pulse, the increase in particular, but
3 the decrease also, is really what leads to the instability in
4 the drifts. But, again, I'm not--

5 KESSLER: The point is that we're talking about during
6 the thermal pulse, perhaps the carbon steel will be there
7 because temperatures are very high. If that's where the
8 rockfall occurs, we should probably try to factor that into
9 our thinking a little bit, too. But, perhaps not because
10 there certainly is the potential for longer term rockfall, as
11 well.

12 COPPERSMITH: How about the ferric chloride issue for
13 this design? Is this a research need?

14 STREICHER: Oh, I think it is because several mechanisms
15 have been discussed as to how ferric chloride may be
16 generated. There are some views that it will not happen. In
17 other words, even though the place is loaded with iron, the
18 pH will be high enough and ferric chloride will not be an
19 issue. That is in the absence of radiolysis that might form
20 nitric acid and hydrogen peroxide. If that doesn't happen,
21 if radiolysis has been cut back enough, however, radiolysis
22 may increase when the steel is gone, right? Is that--

23 PAYER: I don't know. I think that the research need in
24 my mind is exactly what Mike's suggesting, but it's not just
25 a ferric chloride issue. It's what is the prediction of the

1 likely water chemistry completely and important aspects of
2 that are ferric ion and chloride ion, but also nitrate
3 sulfate and how is that modulated by dripping through iron
4 oxide, if there's steel in there, running over tuff, and all
5 that. So, the research need is really getting realistic
6 extreme boundaries on how far can this--what's a realistic
7 range of environment that we anticipate these materials to be
8 exposed to?

9 COPPERSMITH: So, as we concentrate the J-13, what
10 happens? Should those be tests or code calculations or how
11 far do we--

12 SAGÜÉS: Before we go into the--just to make it very
13 clear, it would be the concentration of J-13 on carbon steel
14 target, if you will.

15 COPPERSMITH: For this design, right.

16 SAGÜÉS: Yeah, for the Design Zero, that's right. And,
17 that is certainly not just the water, but also as Joe
18 indicated.

19 COPPERSMITH: Absolutely.

20 SAGÜÉS: But, with the steel and indeed also combined
21 with things such as crushed tuff which are going to be there
22 one way or the other.

23 MACDONALD: If we're concerned about acid, we could
24 backfill with limestone.

25 COPPERSMITH: That's a thought. We're not concerned

1 about acid. There was some quarry operators from the Timber
2 Mountains who had their ears perked up there for a minute,
3 but they've calmed down again.

4 Let's stop right where we are here. Joe is going
5 to show his viewgraph.

6 PAYER: Let me start with this. I think this feeds into
7 giving a perspective to some of the research needs. So, let
8 me run through this.

9 Part of it is what our belief is, what our concept
10 is of the corrosion behavior. So, for steel, we're dealing
11 with a material that when the temperature is above the
12 aqueous temperature--and, I'm defining the aqueous
13 temperature as when you could have liquid water either in a
14 condensed fill or a droplet on the material. Okay. So,
15 that's the aqueous temperature; the dew point, if you would,
16 in another sense. When the temperature is above the aqueous
17 point and the relative humidity is below the aqueous point,
18 if the relative humidity is low, then we would think we're in
19 a dry oxidation zone. I would suggest that we've got
20 reasonably well-established corrosion rates for steel, both
21 in the dry oxidation and the corrosion regime. Okay. That's
22 pretty well-known and there's uncertainty and we can fine
23 tune it, but that's okay.

24 KESSLER: Do we know that, Joe, for very thick steel, as
25 well as for the--

1 PAYER: I think we do because there's experience in
2 fairly thick steel and the oxides are going to spall off.
3 So, you know, you could argue about patterns and things like
4 that, but I think of all the things of uncertainty in the
5 project, I think this is--we're pretty comfortable here. Not
6 everything certainly, but none that could be done.

7 So then, the focus goes to what about the corrosion
8 resistant metals and how do they behave? The corrosion
9 resistant materials we're talking about are C-22 and
10 titanium. Above this aqueous temperature, they have very low
11 oxidation rates. They're not susceptible to significant
12 corrosion rates unless we have an aqueous phase. In the
13 corrosion area, I'm defining this temperature range in which
14 damage can occur by aqueous corrosion. That temperature
15 range is going to be the aqueous temperature. That's the
16 higher limit. When can we get water on the package and then
17 down to some critical temperature below which crevice
18 corrosion will not propagate and be sustained? And so,
19 whenever the corrosion resistant metal is within this
20 temperature range, then that's the potential damage area.
21 That aqueous temperature is defined by the equilibrium
22 boiling point, and as a benchmark or a rule of thumb, the
23 boiling point elevation for a two molar solution is on the
24 order of 105 Centigrade or so. I mean, that's what I recall
25 from a presentation we had last week. You could sharpen a

1 pencil on that. But, when we determine this chemistry, we
2 can determine how much that elevates the temperature, but
3 we're talking about on the order of this type of thing.

4 The other is the scenario that I think both Alberto
5 and Digby brought up yesterday and that is if the package
6 surface was even hotter than that, 150 Centigrade, 200
7 Centigrade, and a droplet hit it, then that could even be a
8 higher temperature scenario. That would give you for that
9 time period an aqueous phase in contact that was--so this
10 droplet on a hot surface, that's going to define the aqueous
11 temperature.

12 The critical temperature for crevice corrosion is a
13 function of the acidity, the oxidizing potential, and then
14 the chemistry; the chlorides, sulfates, nitrates, and so
15 forth. If the critical temperature for crevice corrosion is
16 higher than the aqueous temperature, then there is no damage
17 zone. That's a win-win deal for us. That would be the most
18 admirable situation. If the crevice corrosion temperature is
19 less than the aqueous, then that defines the temperature
20 limit when we're vulnerable, possible to have localized
21 corrosion on the canister, is defined by when we get at that
22 temperature and when we leave it, that then defines for the
23 different scenarios a time period over which the packages are
24 vulnerable. At what time does the waste package temperature
25 enter that temperature range and then when does it come out

1 of it? So, what I did then was take this--

2 BULLEN: Before you leave that one, Joe, a question?

3 PAYER: Yeah?

4 BULLEN: The critical temperature region where it's
5 important also deals with chemistry. So, if you don't have
6 the right chemistry, you're not close to that crevice point?

7 PAYER: Exactly right.

8 BULLEN: So, one of the issues--I mean, this is assuming
9 you've got the worst chemistry available.

10 PAYER: Well, there's various scenarios and that's where
11 I'm going.

12 BULLEN: Okay.

13 PAYER: Yeah, you know, the aqueous temperature is a
14 function of water solution chemistry to a small degree; 100
15 degrees, 105 degrees, a few degrees. But, this crevice
16 temperature is very much dependent on the material we choose
17 and the chemistry that's in contact with that material. But,
18 the other thing that's important to remember is just because
19 we're in this time range and temperature range for crevice
20 corrosion doesn't mean that the package is wet all the time
21 it's in there and it doesn't mean that this process is going
22 all the time. But, it seems to me if we follow this concept,
23 that that defines the maximum time of vulnerability for
24 corrosion processes.

25 BULLEN: Does this also hold for the titanium higher

1 alloys?

2 PAYER: Yes.

3 BULLEN: Even the higher alloys that are susceptible to
4 this crevice issue?

5 PAYER: Well, no, what happens and I'll show you that.
6 But, jumping ahead with that for those higher alloys based
7 on, you know--one of the troubles with Shoesmith is he tells
8 good stories, but he also has in his pocket these data points
9 and it really frustrates you when you're giving a scenario
10 and he confuses us with a data point. So, he has some
11 temperature crevice data for the different titanium alloys
12 and the quick answer is for a couple of the alloys, if the
13 crevice temperature is indeed above the aqueous temperature,
14 there is no region of vulnerability. For the CP titanium
15 with no alloy additions, it's below it; so, you do have a
16 range. So, that's the story.

17 BULLEN: Okay.

18 PAYER: That's exactly the story.

19 STREICHER: That assumes the absence of chlorides?

20 PAYER: No, with the chlorides. Let's come back to that
21 point. Let's follow the argument here. So, what we did then
22 was to take the scenarios that Carl started off with
23 yesterday and said we've got this temperature profile for
24 Scenario 1 and the green line, Scenario 2, under a different
25 condition of a more aged fuel, less heat capacity, less heat

1 production in the canister, and then the Scenario 3 was with
2 ventilation up to 100 years and so forth. If we take those
3 three scenarios--I tried to make this simple, but it didn't
4 turn out simple, I think. But, here's the scenarios I want
5 to set up; scenarios/hypotheses. I mean, none of these
6 numbers are carved in stone and so they're given as examples
7 here. But, I think they're within the range of reality.

8 One scenario is that we're dealing with the nominal
9 water composition of the mountain and the place holder for
10 that is J-13 water. You know, it's mildly alkaline, low
11 dilution, you could drink the stuff, it's no real problem.
12 In that case, T-crevice for all these materials, the C-22 and
13 titanium, is above the aqueous temperature. So, there is no
14 region of damage. We don't have problems, I don't think,
15 with this package in the nominal composition of the mountain.
16 Okay? So then, what are realistic extremes that could occur
17 with that water composition? One of the extremes, going
18 through the waste package expert elicitation and some
19 followup discussions with that, a group of people suggest
20 that pH 2 to 2.5 chloride, sulfate, nitrate of some
21 concentration is a realistic boundary on how extreme that
22 environment could be. So, let's not argue if they're correct
23 or not. I happen to think they're pretty close. But, if
24 that's the case, then what would happen if we consider CP
25 titanium where Grade 2 has a crevice--and, I'm using David's

1 comments here--Grade 2 would have a temperature crevice on
2 the order of 70 degrees; Grade 12, the nickel molybdenum
3 alloy, has a crevice temperature above the aqueous
4 temperature; and Grade 16 with the palladium is well-above
5 the temperature.

6 So then, let's look at three scenarios. I'm going
7 to take the material now that has a crevice temperature.
8 First of all, in J-13, there is no temperature range of
9 vulnerability. There is no time in that temperature range of
10 vulnerability. So, corrosion is not an issue in that. You
11 go to the next degradation level. In the extreme environment
12 represented, say, by that pH2 up there, if the crevice
13 temperature, the critical temperature is 80 Centigrade, then
14 for Scenario 1--and I'm saying we're going to enter that
15 region when we get to 105 and we're going to come out of it
16 at 80. So, if you follow this red curve, we spend--and,
17 again, this was eyeballed in there, we spend about 8,000
18 years in that region of vulnerability. We enter it at about
19 7,000 years and we come out of it at about 15,000 years. So,
20 from the corrosion scenario for that issue, we ought to be
21 doing research. We ought to be thinking about what's the
22 condition on the waste package surfaces at 7,000 years when
23 this water starts being present and how is that going to
24 respond over that length of time?

25 Scenario 2, the same temperature range, we have--as

1 I eyeball it in there, we're in that critical range for about
2 3,000 years. We enter it at about 200 years. That's when
3 we're getting to this 105 C and we come out of it, I said
4 here, at 3,000. Okay. So that we're still spending several
5 thousands of years in that vulnerability, but it's a
6 different time frame. The tunnels and the condition could be
7 significantly different in the drifts.

8 Scenario 3 where we did the ventilation, if the
9 ventilation doesn't get the relative humidity down--and I
10 don't know how that would be--but if you recirculated it, you
11 might spend a time between the 20 years and 100 years here
12 where you could have some moisture on the canister. You'd be
13 in that vulnerability range. But then, when you stop the
14 ventilation, you heat up above that range and then you don't
15 come back down into it again until you get out here. It's in
16 this range here and I suggested that that's on the order of
17 you enter at about 5,000 years and you come out at about
18 10,000 years.

19 So, I think that type of--you know, if we buy into
20 that conceptual view of what's going on in the drifts and
21 that, then that suggests some of the things we need to know.

22 KESSLER: Joe?

23 PAYER: Yes, sir?

24 KESSLER: Lest we take these times of entering and
25 exiting that temperature range too seriously, again I want to

1 remind you, at least for the curve that EPRI drew that are up
2 there, we did it for a totally different system and the time
3 at which you would enter the 105 region would be much
4 different if we had taken into account some of these other
5 things.

6 PAYER: Absolutely. And, based on your saying that, I
7 consider these Carl's curves, not EPRI's. He took them from
8 a couple different sources and he said these are not perhaps
9 unrealistic sort of time ranges. The thing I liked about it
10 is they gave us three different types of behavior.

11 KESSLER: Exactly.

12 PAYER: And, you can see how it significantly affects
13 it.

14 KESSLER: And, when you look at it that way, again it's
15 going to be where in the repository also in terms of time.

16 PAYER: Exactly. You know, you could go through all the
17 scenarios you want to. You could fine tune them. What that
18 says as a research need, we need a better handle on this
19 time/temperature regime when you enter and when you leave it
20 and there's a lot known about that, but to be looked at.

21 Let me give you one more perspective here. If
22 we're talking about corrosion rates of 10 microns per year,
23 then a centimeter of material gives you 1,000 years life. If
24 you talk about a corrosion rate of one micron per year which
25 is not unrealistic--it's the high end for a passive material

1 that, in fact, is passive--you get one millimeter damage in
2 1,000 years. If you talk about .1 micron, you get sub
3 millimeter damage in 1,000 years. So, if we can select and
4 emplace materials that, in fact, do remain passive while
5 they're in this critical temperature range and other
6 temperatures, we can approach the kind of lifetimes that are
7 important.

8 Just to bring that back to what we're discussing
9 today, it seems to me that the research needs, some of the
10 research needs, are, first of all, a better handle on this
11 aqueous temperature; where is it? And, I don't think it's so
12 important about the absolute value of it, but you know, if
13 it's 105 versus 100, that might be a couple hundred years or
14 a couple thousand years in that critical temperature. It's a
15 big deal. The other thing we need is the critical crevice
16 temperature for C-22 and titanium, the materials of choice,
17 and I would suggest that we carry along 825, not because
18 that's the material that's going to be used--it doesn't have
19 sufficient corrosion vulnerability--but it tells us what
20 comfort level we ought to have by going to these higher grade
21 materials because there's uncertainty in that. So, how close
22 are we to that boundary?

23 SHOESMITH: Just on that point, Joe, I wouldn't rule out
24 the 825 as potentially an inner material within the other two
25 because if they last long enough, then 825 will meet the

1 criteria for the crevice corrosion.

2 PAYER: Yeah, that's a point well-taken. Point well-
3 taken. So, I think there's a couple of reasons for including
4 that in there. The other, it seems--

5 COPPERSMITH: Excuse me, Joe, go back to the first. You
6 mentioned temperature and I don't think you've got solution
7 chemistry, as well, but--

8 PAYER: I think that goes into this issue. What are the
9 extreme boundaries on the environment? What we really need
10 to think about is this set--I'm saying this is the ensemble
11 of properties that we're interested in; the acidity, the
12 oxidizing potential, chloride, nitrate, sulfate...ferric ion
13 should certainly be on here. But, we have to think of those
14 as an ensemble, not just what's the pH range and what's the
15 oxidizing potential range because, you know, you can't have
16 them together in some conditions. So, we've got to think
17 about what's the realistic range.

18 So, you know, if you go through that, some analyses
19 have already been done that say, okay, pH2 is a realistic
20 extreme and the oxidizing potential is something on this
21 order and then you look at the ferric chloride. This is
22 physical chemistry modeling and experiments. We're talking
23 about water chemistry under various conditions, dripping it
24 through corrosion products, dripping it through crushed tuff,
25 heating it, cooling it, evaporating it. These are

1 electrochemical and corrosion experiments, again fairly
2 short-time experiments, not real long-time experiments, very
3 doable as a function of temperature and these environments.
4 And, these extreme boundaries are taking this sort of
5 solution chemistry to physical chemistry and going through a
6 rational description of what kind of scenarios make sense.
7 To my mind, these are high-priority research needs for the
8 waste package design and performance assessment issue.

9 STREICHER: Joe, why is 825 up there again?

10 PAYER: 825, from my perspective, it's up there--we know
11 it's a less corrosion resistant material than the C-22 not
12 because it's a candidate alloy, but knowing where the
13 boundary is of acceptable behavior for 825 could give us a
14 feel for how comfortable we might want to be with C-22 and
15 titanium. Are we right on that edge of behavior or not?
16 David brings the standpoint, one of the options we had on our
17 material here was to put the highly-corrosion resistant
18 material, titanium or C-22, over some other nickel alloy that
19 perhaps had lesser, but still good corrosion behavior. That
20 was the rationale.

21 STREICHER: 825 has 2% copper in it.

22 PAYER: Yes, sir.

23 STREICHER: Which are in there for sulfuric and
24 phosphoric acid service and the copper is very detrimental to
25 chloride resistance.

1 PAYER: Okay. I would not suggest that 825 be brought
2 back as a candidate material for the waste packages, but it's
3 a material that the project has some significant experience
4 in data on. I could see in the short-term tests,
5 electrochemical tests and that, carrying it along again for
6 this idea of the comfort level. How much do we buy by going
7 to the C-22 and titanium? And, the other reason would be to
8 give some technical basis for somebody that, you know, 20
9 years from now or whatever said, well, jeez, C-22 is okay,
10 but it's really expensive. Why don't we drop that to 825?
11 This data would show if that was a rational decision or if
12 that was really a major danger point. I think your gut
13 feeling is it would be very dangerous.

14 STREICHER: Disaster.

15 PAYER: Disaster. So, let's have some data on file in
16 the records under Yucca Mountain conditions that would, in
17 fact, document that it is a disaster and that somebody just
18 can't make a decision.

19 SAGÜÉS: Any idea about the relative cost of 825 versus
20 C-22?

21 PAYER: Less.

22 STREICHER: Oh, much less. But, a comparison would be
23 Carpenter 20 which is close in stress corrosion resistance
24 than nickel contact to 825, but is more resistant to pitting.
25 I have a table that shows that here if there's some interest

1 to see that.

2 PAYER: Well, anyway, that's for what that's worth.

3 PARIZEK: What I see in all of this is a considerable
4 range. I mean, that 20 year to 100 year, Category A, you
5 could talk about the chemistry of water at Yucca Mountain
6 very well. I guess, the panel you've been working with,
7 Kevin, that deals with heating and the chemistry of that
8 water, you can characterize it. As soon as you get into the,
9 seems to me, 5,000 to 10,000 year range or 7,000 to 15,000
10 year range, now we really have climate and we have the
11 geochemistry of that water and how that evolves. So, the
12 question, does the program have a grip on that part of the
13 story because you say these are the periods of going in and
14 going out of vulnerability, but the chemistry comes with that
15 and we--

16 PAYER: I understand. What you don't have at this real
17 long time brings in the climate uncertainty, perhaps the
18 infiltration, flux rates, things like that, but you're well-
19 beyond the thermal effects. I would suggest that the thermal
20 effects have a lot more potential for shifting this
21 chemistry, what's there and what's not there, than the
22 general flux through it. So, I would make an argument that
23 perhaps we would have a better job of projecting what that
24 environment nominally ought to be from a water chemistry
25 standpoint out in this range. My guess would be that the

1 nominal water that's coming in would be returned a lot closer
2 to what's in the ambient mountain conditions because you've
3 gotten away from, I would guess, the uncertainty with the
4 thermal, chemical, mechanical effects which I think are going
5 to be very difficult to sort out in certainty.

6 But, the other point is that that uncertainty in
7 water chemistry doesn't concern me so much because I think
8 it's mostly processes that are going on at the waste package
9 and in the crevices at the waste package and the corrosion
10 products of the waste package that are modulating this
11 environment, not the thermal, chemical effects in the large
12 dryout area and so forth. From a corrosion standpoint, I
13 don't think I care if it's pH6 coming in or if it's pH10
14 coming in. It's what happens to it once it gets in the
15 crevices and so forth.

16 KESSLER: If it was more dilute than J-13, would you
17 care?

18 PAYER: I don't--you know, because you're going through
19 concentration mechanisms and things like that--in my overall
20 order of caring? I mean, sure, I care, but they might--

21 KESSLER: But, now, you're talking about several
22 thousand years in the future where the thermal period is
23 over. You may not be concentrating anymore, and if you're
24 talking about pluvials, you may have situations where what's
25 actually getting into the drifts is more dilute than J-13.

1 PAYER: I think you're still going to be bringing in a
2 solution that has some chloride, it has some nitrate, it has
3 some sulfate, and--you know, by evaporation, whatever. So,
4 my quick thought for that would be I think it's a secondary
5 sort of an issue.

6 MACDONALD: Let me just make a comment on this business
7 of concentrating. I can say this from firsthand experience
8 because we just finished a fairly large study for EPRI and
9 Peter Miller on chemistry of steam generated crevices. First
10 of all, the concentrating factors can be very large, 10^6 to
11 10^7 on a heat transfer surface. But, secondly, the small
12 changes in the chemistry of the input solution, bulk solution
13 can swing the pH to very acid or very alkaline and, in fact,
14 it's very difficult to determine up front which direction
15 it's going to go. So, while we're assuming that the
16 concentrated solution in the deposits and whatnot is going to
17 go to 2.5, maybe it will go to 11. This is one of the
18 factors that the operators of pressurized water reactors are
19 struggling with at the moment. It's called molar ratio
20 control. How do you control the bulk water chemistry to get
21 the chemistry in the crevice that you want? So, I don't
22 think that we have a handle on exactly what solution is going
23 to exist, at all.

24 PAYER: I think that's true, maybe. But, we can also
25 balance it by which directions does it matter if it goes?

1 For these materials, it matters if it goes acidic and highly
2 oxidizing--

3 MACDONALD: I totally agree with you.

4 PAYER: And then, if it goes to mildly alkaline or
5 something, we may not be able to rule that out, but we don't
6 care if it goes there.

7 MACDONALD: No, I totally agree with you.

8 SHOESMITH: I had a question. Does it make any
9 difference what the anion mix is as to how that pH
10 fluctuates?

11 MACDONALD: Yes.

12 SHOESMITH: So, are we likely to get that kind of
13 fluctuation in sulfate dominated as opposed to the chloride
14 dominated situation that we have here--that we think we have
15 here?

16 MACDONALD: I can't answer that because we haven't
17 looked at the particular sulfate system. But, oh, yeah, you
18 control certain cations to certain anions in bulk order that
19 determines the final chemistry that you get. It's almost a
20 step function. It swings one way or the other.

21 SHOESMITH: But, would you be willing to speculate that
22 if you have anion content, such as sulfate and probably
23 nitrate, that you're less likely to get these wild swings in
24 pH?

25 MACDONALD: No, I wouldn't speculate on that.

1 SHOESMITH: Okay.

2 COPPERSMITH: It sounds to me like that--I roll that all
3 together in terms of the concentration chemistries that would
4 develop as a key research need in the presence--and for this
5 design, the presence of carbon steel. You mentioned a better
6 definition of the temperature/time history and actually that
7 is being developed, but potentially, I guess, the chemistry
8 that goes along with that, that kind of history is a function
9 of time. I would assume that those are doable things.
10 People are looking at the full concept of refluxing,
11 dissolution of minerals that have precipitated along
12 fractures, and so on to see whether or not certain elements
13 are concentrated in that process. Again, those all go
14 towards the environmental condition, but again more of the
15 specific localized environmental conditions, I think, that's
16 the key--

17 PAYER: Let me just try to make the point again, though.
18 I think that that re-precipitation and what comes out and
19 what dissolves along the fracture surfaces and that has, as I
20 understand it, significant impact on radionuclide transport,
21 retaining it or speeding it up and those sorts of things.
22 From the corrosion perspective alone of the waste packages
23 before they are penetrated, I think they are of a less
24 importance. So, they're important to the project, but it's
25 after you get penetrations and you start moving

1 radionuclides, I think, and then it becomes a very
2 complicated, even more complex situation.

3 SAGÜÉS: By the way, talking about water chemistry,
4 we've said they don't want to fixate on J-13 which is a
5 couple of miles away from the repository. Also, you must
6 remember that there may be some local variations in the water
7 chemistry of the footprint of a repository, and could also if
8 we have, for example, a variation of something which is a lot
9 richer in chloride than J-13 is which may give indications--
10 have examples on how much we want to think about titanium.
11 So, certainly, the idea here is to look at what may be
12 present--

13 COPPERSMITH: Good point. Hopefully, you're taking
14 notes on all these research needs as we go along. At a
15 break, we'll take a look and make sure. Going back to Joe,
16 be sure we get copies of Joe's viewgraphs because he had some
17 excellent suggestions.

18 DI BELLA: Yeah, I just asked Brenda to make a copy for
19 each person on the Panel. So, we should have that by the
20 break.

21 COPPERSMITH: Let me go back and ask--on this design, I
22 do want to deal with radiolysis a little bit and see whether
23 or not that, in fact, is something that is worthy of pursuit.
24 But, Joe, in your suggestion for the corrosion resistant
25 alloys, titanium and C-22, I guess the research need there is

1 to look at basically when you would slide into and out of
2 when there was a susceptibility, when you would initiate
3 localized corrosion and when you would repassivate.

4 PAYER: In the context of what I said, it would be
5 defining that critical temperature below which you could not
6 propagate that sustained crevice corrosion. It's not so much
7 an initiation issue, but what is the temperature which we
8 have some certainty at which it will not sustain and grow any
9 longer. And, there's several ways that have been suggested
10 to look at that. Short-term electrochemical tests certainly
11 start to give boundaries starting with crevice specimens
12 where they are intentionally put into more extreme
13 environments where you'd start and grow the crevice. You
14 start the damage and then bring it back into the realistic.
15 These are not--you know, they're not brand new. The project
16 and this program is not inventing those. They can take
17 experimental methods and techniques that have been used with
18 others and some of the rationale behind it. But, it's
19 necessary to be done in these environments.

20 COPPERSMITH: Okay. The question that I have, my
21 understanding is that those types of experiments are more
22 short-term. They deal with the initiation repassivation
23 issue. But, what about the propagation issue? What about
24 once you're in--I mean, where we're dealing with wall
25 thickness here as a potential barrier, the time involved, and

1 the actual given a localized propagation, dealing with the
2 growth law, those issues are much more difficult to deal
3 with, I think, experimentally. Is that a research need? Is
4 that something that should be pursued?

5 SHOESMITH: I think it's a critical need for the C-22.
6 I don't think you'll get a growth law. I think, what you'll
7 get is you'll find that it stifles very quickly. So, you'll
8 find that you can't propagate it as a function of all those
9 parameters that you're worried about which are environmental,
10 concentration, and oxygen. You would have to force it to
11 start if you can and then just demonstrate for one reason or
12 another it's not going to propagate.

13 COPPERSMITH: Would those be the same type of tests that
14 Joe's talking about?

15 SHOESMITH: They will be similar, yeah. There are a
16 number of experimental ways to attempt to do that, but short-
17 term--that kind of electrochemical test then is certainly the
18 place you would start. There are other techniques whereby
19 you could monitor crevices and you can see when they start,
20 you can get signatures for when they're going and when
21 they're not going. So, there are a number of ways you can do
22 it. If you want to get propagation done, sooner or later,
23 somebody has to look at the depth of a hole in a piece of
24 metal and that's not an electrochemical investigation.
25 That's metallography. This kind of test backed up by, you

1 know, a kind of metallographic examination would do it.
2 There are none complex. There's no complex experimental
3 method.

4 COPPERSMITH: Okay. This type of thing will deal with
5 many of the designs that have C-22 or titanium alloys
6 somewhere in their mix. What about different grades of
7 titanium? We've talked a little bit about that. Is that
8 something that--should these tests be done on different
9 grades? One of these that we need to do, now that Dr.
10 Shoesmith is in two weeks as a professor, is to get him to
11 publish all of those datasets in some way. So, that's a
12 research need.

13 SHOESMITH: Some of them are written up. A lot of them
14 aren't written up. I would not recommend that until we write
15 up what we've done that anybody do anything on the crevice
16 corrosion of titanium.

17 COPPERSMITH: You've already done it all.

18 SHOESMITH: Well, you know, we've been at it a long
19 time. We just have to write it up. I think we know exactly
20 how those materials function in crevices. We know, for
21 instance, that sulfate kills the acidity in a crevice and
22 stops the propagation. We know that carbonate does the same
23 thing. We know silicate blocks it. We have a lot of data of
24 that kind. I don't think the experimental need on titanium
25 is necessarily crevice corrosion. So, you might want to take

1 another look at titanium-16, you know, the palladium
2 containing alloys, a little bit more aggressively than we
3 did. Beyond that though, I think there's still a need based
4 on some of Digby's comments from yesterday that the passive
5 corrosion process itself should not be ignored. If you're
6 going to rely on getting 10^5 or 10^6 years of life out of this
7 material, either C-22 or titanium, then some research should
8 be directed to try to demonstrate there are no events which
9 could ruin this scenario for you. This is a long time and
10 this is becoming critical in the performance assessment
11 within those line times.

12 COPPERSMITH: How do you explore that?

13 MACDONALD: Can I just make a comment on that? I just
14 had a graduate student finish his PhD thesis on titanium, and
15 in it, he measured the dissolution rate of the oxide film in
16 various solutions. So, I think reasonable estimates could
17 probably be made of the passive corrosion rate for titanium,
18 but not for C-22. I don't know of anyone who has--

19 SHOESMITH: That would be valuable data. There is some
20 already out there in stranger environments than what we would
21 anticipate here. That would be very valuable, but I don't
22 think it's enough. I think one has to know what are the
23 consequences if you do this in an acidic environment, then
24 effectively you do get a balance between film formation and
25 film dissolution. So, you can effectively make the case that

1 you have a passive layer that stays roughly the same because
2 it's balancing its production and its destruction. If you go
3 to slightly more neutral conditions and, in fact, you have to
4 deal with what's the long term film growth, how will it
5 recrystallize, is the volume expansion going to crack this
6 thing in the long-term, what will dripping silicates and
7 calcium do to it, there are a few questions there, you know,
8 which dissolution is not necessarily the answer to it.

9 MACDONALD: In fact, to get any measurable results at
10 the time of a PhD thesis, if I can use that unit, you have to
11 go to really concentrated sulfuric acid and throw a little
12 bit of fluoride on it then, as well.

13 COPPERSMITH: That must be a classic problem dealing
14 with passive dissolution. I mean, right now, though, say,
15 getting at the passive dissolution rate for this design or
16 the passive dissolution rate of C-22 is the controlling
17 parameter for the performance assessment.

18 PAYER: The other point is what we need to establish is
19 a realistic defensible upper limit. If it's below--you know,
20 if we could say it's .5 microns per year, if we know it's
21 less than that and it's hard to measure it below that, but
22 that's fairly certain, then we win.

23 COPPERSMITH: My question in terms of research needs is
24 how do we establish what that limit is? How do we establish
25 in a reasonable time period or maybe it can't be done in a

1 reasonable time period.

2 PAYER: Oh, no, I think you can. We just said that
3 they've attacked the growth rates on titanium and on other--

4 COPPERSMITH: Isn't the classic problem this is passive
5 dissolution? The classic problem is you don't put it in
6 aggressive--I mean, you want to have something measurable,
7 but you have a resolution problem being able to measure it in
8 a reasonable period of time.

9 PAYER: Well, you're not going to do it by weight loss.

10 COPPERSMITH: I would hope not. That's not very
11 passive. I just wondered how is this element--I've seen all
12 the test results that normally you have a weight loss and
13 everything else and say, well, this is below detection, below
14 this limit over and over, and that likely is what would
15 happen. We put these things into these types of solutions
16 with C-22 in the next, you know, 100 years, but is there
17 another way to approach this either through modeling,
18 experiments?

19 SAGÜÉS: Digby can tell you several clever
20 electrochemical transience methods to assess the rate of
21 dissolution.

22 SHOESMITH: I would just like to add the portion that I
23 don't think it's always dissolution. I think this is film
24 growth recrystallization which doesn't necessarily involve
25 dissolution since we're going to deal with a neutral

1 environment. That's slightly different. That's in a way
2 saying that you can get back to carbon steel scenario where
3 after, I don't know, 2,000 years, the TiO_2 film is thick
4 enough that it will invite rupture and then what you'll have
5 is a step-wise film growth process which is linear. I'm not
6 sure how one goes about doing these things experimentally. I
7 mean, there are electrochemical ways to push film growth, but
8 you inevitably distort it from the way the film is naturally
9 grown. But, it's not necessarily just dissolution.

10 MACDONALD: I agree with Dave. In fact, for the valve
11 metals and the zirconium tungsten and so forth and titanium,
12 what ultimately controls the corrosion rate in the long-term,
13 particularly environments that we're talking about, is the
14 outer layer. Okay. The outer layer which is the
15 recrystallized layer becomes less and less porous and
16 restricts access of water and solutions to the barrier layer
17 which provides corrosion protection in the short-term. So,
18 you do have to consider the electrocrystallization phenomena.
19 But, there is one way of doing this and that is using the
20 quartz crystal microbalance technique. We can measure very,
21 very small changes in mass.

22 PAYER: Perhaps in the context in this meeting, it is an
23 area that needs research. There are some approaches to it,
24 but it's going to be a combination of some conceptual
25 modeling, describing the processes, and it's not--

1 COPPERSMITH: My point of view and I hesitate to use
2 just passive dissolution, but it's a process when you're
3 outside the window of susceptibility and you're not in an
4 area of localized corrosion for these corrosion resistant
5 alloys, there are processes over long time periods that will
6 operate. Performance assessment will need those processes
7 and rates over this time period.

8 PAYER: I think what David is suggesting is we don't use
9 the term passive dissolution, but it's the passive corrosion
10 rate or the passive--

11 COPPERSMITH: That's right. Particularly dealing with
12 these time periods, perhaps other things go on.

13 SHOESMITH: This is a much less critical need than
14 trying to demonstrate that there are no localized--

15 COPPERSMITH: Oh, absolutely. That's a good point.

16 SHOESMITH: It's not something that needs an answer
17 before LA. This is something that needs an answer over a
18 period of time.

19 SAGÜÉS: I don't know if I agree completely with that.

20 COPPERSMITH: On the priority?

21 SAGÜÉS: On the priority. I think that the very long-
22 term stability of passive layers is at the core of what we're
23 trying to achieve here. The one thing that one could
24 demonstrate when looking at the windows of susceptibility
25 is that there isn't any clear recognizable catastrophic type

1 of failure, like, for example, a pit or a crevice cutting
2 through the material very easily. But then, that means that
3 we are saying effectively that we cannot identify a known
4 mechanism. And, what we're saying is, well, then, this thing
5 must last for a very long time. I don't know. I think that
6 there is another fundamental issue, some long-term stability
7 of a passive system, that then become important. There is a
8 number of possibilities that one should be looking at. There
9 is, for example, all kinds of defects and precipitates in the
10 bulk of the material. A corroding passive layer, if you
11 will, is going to be slipping through those things as a
12 function of time. If there is such a thing as an
13 accumulation of those defects out there, that is one issue.
14 The other benefit that we're not taking into account in this
15 is that we're going to be dealing, I made a very quick
16 calculation, with 500,000 square meters worth of passive
17 surface. The opportunity for something to happen in that
18 area is a lot larger than when you determine in the
19 laboratory test where you may have a square foot of material.
20 And perhaps we should be concentrating on thinking about
21 what are the possibilities of maybe even just plain
22 microdefects, of course it's a question of all the welds.
23 We're having a lot of surface and those things that may be
24 negligible in small size containers now may become all
25 important. And then, there's, of course, something that

1 Digby has mentioned and other people, as well, is the
2 question of the time scale of laboratory experiments versus
3 the time scale of what is
4 happening over here. We can show that under certain
5 circumstances a pit would not develop in an environment with
6 a certain potential. Say, in a three year long test. And
7 now that establishes a certain probability for a given area.
8 Now, how validly can we extrapolate that to, say, 500,000
9 square meters over 1,000 years or about 10,000 years?

10 MACDONALD: Well, the only way of doing this is on the
11 basis of determinism. I've come back to this. The only thing
12 that we can rely on for sure are the natural laws. You know,
13 I get very uncomfortable in trying to extrapolate corrosion
14 data from 10 years, 15 years, out to 10,000 years on the
15 basis of empiricism. It just won't work. I don't know of
16 any other system where it's worked then for much shorter
17 times then. The only philosophy that will work is
18 determinism. You know, it's like NASA firing a rocket to the
19 moon. Okay? They don't fire rockets off every hour. They
20 find which two straddle the moon and then divide that time up
21 and then fire a bunch more. That's the empirical way of
22 doing things. They do it deterministically because of, you
23 know, Newton deriving his laws of motion. That's the only
24 way of going.

25 BULLEN: Alberto's comment actually brought up another

1 issue that I'd forgotten about, but Carl in his opening
2 remarks yesterday basically commented on the 350 degree C
3 clad unit. That is a limiting factor in fabricability of the
4 issues that we're talking about. The inter-metallics in, for
5 example, C-22 that are formed in the heat affected zone of
6 the well, that are potentially formed in the heat affected
7 zone of the well, basically tell you that as a metallurgist,
8 you'd love to have everything be as base metal. So, the
9 question that I have to sort of put on the table to the
10 experts here today is that do we want to adhere to a 350
11 degree C temperature limit or can I post-weld anneal or post-
12 weld heat treat at 1100 C for an hour so I know what the base
13 metal looks like? The reason I'm asking that is that clad
14 credit may be an issue, but I'm not sure that it's a
15 licensable issue. That's Dan Bullen talking, not the Board.
16 And, I guess, I'd like to know if you would feel much more
17 comfortable as opposed to fabricating it and leaving it with
18 a heat affected zone at the weld region or if you'd want to
19 post-weld heat treat which was my personal opinion. So, I
20 toss that one out because the inter-metallics long-term might
21 be a problem.

22 COPPERSMITH: Is this a research need?

23 BULLEN: Yeah, actually it is a research need because
24 basically if you take a look at it, you could put it to bed
25 by saying we're going to post-weld heat treat everything.

1 COPPERSMITH: Yeah, but wouldn't that be then--what's
2 the research need? Is the research need then to evaluate the
3 pros and cons of--

4 BULLEN: You don't want to do long-term phase--right
5 now, when we talk to people at Livermore, they want to do
6 long-term phase stability of C-22 and put it in an autoclave
7 and cook it in an oven for 20 years. Now, that's one way to
8 deal with the issue of doing it for inter-metallics. The
9 other way of dealing with it is say we're not going to have
10 inter-metallics because we know what the base metal looks
11 like because I don't have a heat affected zone. I've got
12 essentially a material that's not going to be annealed in
13 those conditions during the welding process.

14 PAYER: I think along those lines that the research need
15 is to get a better handle on and documentation of what the
16 fabrication manufacturing placement issues are regarding
17 corrosion. And, we haven't talked, at all, about stress
18 corrosion cracking here, but most of the folks that address
19 that with some background and experience say that what you
20 really want to do is minimize stress. You want to do all the
21 things that favor and avoid everything you can that's
22 detrimental from a stress corrosion cracking standpoint
23 because you may not be able to make it go totally away. But,
24 you certainly know things that make it more likely and worse.
25 Those are tied up in the fabrication issues; things like

1 shrink-fit, things like weld stresses, structure and
2 stresses. And, to date, those have been dealt with in not
3 much detail, I think. There is some information available.

4 BULLEN: I guess the follow-on question for you, Joe,
5 would be do you think the 350 degree C temperature limit is
6 an artificial restraint that we don't need to have? I mean,
7 is it worth it to forego the cladding credit?

8 KESSLER: We can't answer that here, Dan. The policy
9 decision is much more--

10 BULLEN: Oh, I know it's a policy decision, but if I
11 didn't have to worry about clad credit which is one of the
12 open outside the box areas that's here and I wanted to
13 fabricate this, I can tell you that my choice would be to
14 post-weld heat everything that's there.

15 PAYER: One of the things that comes along, it seems to
16 me that having a temperature limit on how hot the internals
17 of the package can get makes sense. If clad credit is the
18 primary rationale for putting that in 350 Centigrade, I guess
19 my gut feeling is I wouldn't want the packages to be lot
20 hotter than that inside when they're in place in any case
21 because it maximizes the thermal types of issues, thermal
22 chemical effects on the mountain. So, that's my more concern
23 there. But, I guess, you're not talking about that. You're
24 talking about--

25 BULLEN: No, I want 1100 degrees C for an hour. That's

1 all I want.

2 SHOESMITH: I'd like to comment on this one. The
3 question of cladding credit is one issue, but the question of
4 heat treatment is another. What I saw in the TSPA meeting in
5 Albuquerque suggested that juvenile failures have a big
6 effect on release of things like technetium. If that is the
7 case, then the great quality assurance issue in the program
8 will be can you close this package, can you guarantee that
9 the closure weld is good and that there are no faults in the
10 design? That may dictate that you have to do a heat
11 treatment just to make that assurance. It may be very
12 difficult in the long run to live with that criteria in that
13 you don't go above 350 degrees inside the package.

14 KESSLER: A couple of things. First of all, the early
15 container failures just depends on whose model you're looking
16 at. If you look at DOE's, I think you have an issue. If you
17 look at NRC's, their early container failures, I suspect is
18 due to a lot of rockfall that they're assuming breaches
19 containers and happens early. Based on my interpretation of
20 that NRC TSPA, that's what causing it. You can heat treat
21 all you want, but if that's what they're going to make for an
22 assumption, you've still got that problem.

23 I think that if we're going to try to put this in
24 terms of research needs, let's back up a step. This idea of
25 taking credit for cladding or not is just one of many options

1 that DOE would have in terms of how they're going to try to
2 demonstrate safety. If you want to do research needs, back
3 it up and say, okay, if you post-heat treat it, what would
4 the quantitative benefit be? Stop there. What research
5 needs need to be defined so that if post-heat treating could
6 be done--and, of course, you have to go into how that is
7 actually carried out--what is it that buys you, and stop
8 there.

9 SAGÜÉS: By the way, such sobering statistics, as well,
10 would be there could be about 100,000 linear meters of non-
11 heat-treated weld in the repository.

12 COPPERSMITH: With that, we're going to take a short
13 break. Actually, I've heard Dan or Dave, someone has given
14 the length of welds before, the length--the whole repository
15 is remarkable when you look at things in linear feet and, you
16 know, foot pounds per dissertation, things like that, other
17 units.

18 KESSLER: We may go on to another kind of design after
19 the break. I'd just like to say again as a John Kessler
20 statement here, given the way I've seen TSPA/VA results come
21 out recently, I just can't imagine a much higher research
22 need than demonstrating that C-22 is going to behave the way
23 that it looks like it behaves in the recent TSPA/VA.

24 COPPERSMITH: I missed--what was the first part? That's
25 more important than the studies of C-22?

1 KESSLER: No, I said I can't imagine there would be much
2 more that would be important to DOE given the way they're
3 claiming credit for C-22 in the TSPA.

4 BULLEN: I agree and I would say if you can reduce the
5 uncertainty by getting rid of the heat affected zone in the
6 weld, you've gone a long way to reducing that 100,000 meters
7 --is that what you said, Alberto--of potential failure sites
8 within the site.

9 COPPERSMITH: How do you really feel about this, Dan?

10 BULLEN: Before we break, I want to mention that lunch
11 is the same as yesterday. So, if you want to go pay for
12 lunch, you should do it right now.

13 COPPERSMITH: And, we're going to try to reconvene at 20
14 after.

15 (Whereupon, a brief recess was taken.)

16 COPPERSMITH: I have a request for a short presentation
17 by Paul Craig. Apparently, he in concert with others has
18 come up with the solution to all of our problems in a single
19 viewgraph. Actually, these are some ideas for thought.

20 CRAIG: We have independently rediscovered things that
21 are extremely well-known to the Department of Energy and
22 that's as it should be. But, remember, the purpose of today
23 --this is barely readable even here, but we'll read them to
24 you. The purpose of today is to think more broadly. So it
25 does seem appropriate to at least spend five minutes

1 reminding ourselves that once you open up the possibility of
2 a small canister, you have other possibilities.

3 What we've suggested here is if you think about
4 small tunnels, small canisters, the possibility of long-term
5 surface cooling, you have then the possibility of drilling
6 the tunnels early and monitoring them so that you can leave
7 out the places that drip and not use them and monitor
8 possibly for decades. You have the possibility of angled
9 emplacement. This is a tunnel with angled emplacement
10 possibly going not just left to right, but up and down, as
11 well. You have the possibility of having a truck that will
12 come in here that would inject the canister into a tight
13 fitting tunnel using a hydraulic jack so that it could be
14 easily emplaced and with any luck easily retrieved.

15 Now, there are a million problems and we've been
16 told about a bunch of those wedging problems, mining machine
17 problems, and so forth. Nevertheless, there do seem to be
18 some advantages to this kind of approach, and if you're going
19 to think about a material canister that is only going to have
20 C-22 and/or titanium, it's going to be pretty thin. It's not
21 going to have the thick iron either on the outside or on the
22 inside and that means that it's less robust than the old type
23 of canister. Putting it in tight fitting environments means
24 that it's less vulnerable to rock drops.

25 Jeff, your turn?

1 WONG: Thank you, Paul.

2 CRAIG: Now, you can go back to the regular discussion.

3 COPPERSMITH: While they're here, are there any
4 questions on this particular design concept? We actually
5 have a design--you'll see when we get down to the bottom--
6 called the smaller canisters that we were going to talk about
7 or had identified primarily because of the potential research
8 needs that might be associated with that type of design. So,
9 we will get into some of that.

10 Are there other issues, other questions we'd like
11 to ask these fellows while they're here?

12 PAYER: I would just support it. I think it is worth of
13 serious consideration.

14 WONG: Dave Haught and company explained to us that the
15 DOE did look at this design and there were a number of
16 reasons why the design was rejected. I mean, maybe we could
17 allow them two minutes and they could tell us why the design
18 was rejected originally.

19 CLARKE: Normally, I wouldn't jump up like this, but
20 you've really struck a wonderful hot button. This is a
21 design, by the way--and I don't know if you talked to
22 somebody here. Gene Roseboom, I notice, was in the room
23 yesterday. This was a design that's actually in publication
24 in 1982. Ike Winograd, the one that recommended Yucca
25 Mountain in the first place, and Gene Roseboom had this

1 particular design and it's based on the ancient Pharaohs
2 which we have 5,000 year analog of bones still intact with a
3 slight slant. It also was suggested in our discussions of
4 the same kind of thing about a year ago, it is one of our
5 alternatives for LA after VA. The only thing that we did
6 different is we wanted to put a solid ceramic insert into
7 each one of the boreholes to act as a drip shield so that you
8 could always get your packages in and bring them back out and
9 then you would have a shield lid on the outside, just a drop-
10 down shield lid, so you could walk in and out of the drifts,
11 scratch your head, and lay the blueprints out.

12 WONG: That's one vote.

13 CLARKE: I will add the reason it was rejected was they
14 said it was too expensive to drill the boreholes and, of
15 course, there was comments that you can't do this or
16 whatever. I talked to the underground people and they said
17 they could drill those boreholes by hand. They didn't even
18 need a machine. If you take and do all of the cost analysis,
19 it certainly is no more expensive than what we have right
20 now.

21 WONG: Thank you.

22 COPPERSMITH: Tom, did you have anything else? Is there
23 any additional comment you'd like to make?

24 DOERING: Back in the SCP days, back in the '82 time
25 frame, '83 time frame, we did look at this from the SCP/CDR

1 time. Basically, we're going from--the differences are here
2 essentially from around 15,000 waste packages as they stand
3 right now to, with a smaller borehole design from the SCP
4 design, was 35,000 to 40,000 waste packages. This was also
5 looked at for the vertical borehole and the horizontal
6 borehole and actually put the packages relatively far into
7 the system where they had a 40 foot hole to begin with. And,
8 remembering the waste package doesn't change in length due to
9 the size of the waste package, it's always going to be on the
10 order of the five meters because that's how far--you know, 14
11 feet to 15 feet because that's how long the waste form is.
12 So, if we do do the herring bone and do borehole, you do need
13 to go back in that far, that deep to get them emplaced. And
14 then, to get them in, you do have to take a look at the drift
15 emplacement, how far do you have to move it and angle it?
16 What some of the earlier studies show, the 5-1/2 meter drift
17 would actually have to grow a bit to get that angle to come
18 in right so you don't essentially make the wall real thin on
19 one side. And, you do have a very similar thermal pulse on
20 that because within 10 years of our calculations--we looked
21 at the 10 year time frame--the drift was as hot as if you had
22 indrift emplacement because you do get that temperature
23 coming in on the drift. And, you truly do get some shielding
24 benefit on that one. The emplacement time frame when you
25 pushed it in was the real critical point. If you got it

1 halfway in, now you have something that's sort of half in and
2 half out and that was one of the critical activities back in
3 the SCP that they described in that time frame.

4 So, with that, the additional costs of the
5 packages, you actually do have to look at more welding, more
6 QA on the packages if you go to many more of them and
7 actually calculated that out, then your feet of welding is
8 increased dramatically between the larger and the smaller
9 package because you have so much more smaller package. Also,
10 there was a system--say, you've done that and looked at if
11 you don't use standard size pipe, if you start rolling your
12 own pipe in the smaller diameter, if you use again the carbon
13 steels or even any kind of metals, turning the radiuses
14 become more difficult and the larger radiuses are more
15 generous to use. So, you can actually roll them easier. So,
16 there's some fabrication issues to be done in that activity,
17 too.

18 The interesting thing was also when we did some
19 more thermal work on that area was that the waste package
20 indrift was actually cooler than the waste package in the
21 borehole with a third or a quarter of the waste form inside
22 of it just because it couldn't reject the heat again. The
23 major rejection of the heat on the indrift is through
24 radiation and you can do some convection or blast cooling
25 through that area. Then, the rock is relatively poor thermal

1 conductivity. That's the benefit of it actually also because
2 now you're essentially holding it as a thermos and you get
3 sort of a warm front in there, if you like, you know, or a
4 thermal protection of it keeping it above boiling.

5 So, there are a lot of different tradeoffs that had
6 gone on in the past. From the earlier evaluations in '93 and
7 '94 time frame between borehole and the drift emplacement,
8 the performance and the cost was lower for the indrift than
9 the borehole and so that's why it was moved forward and
10 adopted at that time.

11 Thank you.

12 COPPERSMITH: Thank you very much. I got a call from
13 Bill Clinton over the break. He said to give a message to
14 his appointee, Dan Bullen, that he would like 10⁶ years
15 cladding credit. So, if you could send that to him right
16 away?

17 BULLEN: Do I resign now or should I resign at the end
18 of the meeting?

19 COPPERSMITH: We got well into heat treating closure
20 welds on waste cans and all that stuff and we will get back
21 to that. In fact, I guess there's some research needs
22 associated with that and tradeoffs. But, I want to be sure
23 on Design #1 that we've covered the research--or Zero that
24 we've covered the research needs. We got a little bit--going
25 back about an hour ago, there was some discussion about

1 whether or not--oh, by the way, I did check with Carl. He is
2 taking notes on all of this. So far, he's got about a dozen
3 or maybe less research needs that we have discussed in this
4 process. But, we began to talk a little bit about
5 radiolysis, the potential for that effect, whether or not it
6 was important, and then we stopped. Is this in the area for
7 Design Zero that you feel is worthy of additional research?

8 SHOESMITH: It's hard to imagine that it's an issue for
9 Scenarios 1 and 2, but 3 is a possibility. I think
10 radiolysis is something that eventually can be written out.
11 I would not recommend any studies. There are two issues. If
12 you go with C-22 on the outside, there is evidence that shows
13 that the C alloys, basically C-4 is with the European study,
14 it does have a sensitivity to pit and crevice corrode at high
15 dose rates. They have that information as a function of dose
16 rate. I just can't remember where the lower dose rate is
17 when that disappears. It's the submerged effect and not a
18 vapor effect. Titanium will have no--there will be no
19 consequences to using titanium. It just likes it. It loves
20 radiation. It thickens the films, blocks hydrogen
21 absorption, kills crevices. The iron system will react, but
22 iron 2 and iron 3 is the best radiolysis moderator known to
23 man because the iron 2 and iron 3 redox couple is so rapid
24 that it just soaks up the oxidizing and reducing radicals or
25 it drives them effectively to recombination. So, dose rate

1 effect is much, much lower. It will react, but it will not
2 be a big effect. All that information is out there. It just
3 needs to be written.

4 BULLEN: A question on the iron 2 and iron 3. Does that
5 assume that you have an inherent oxide layer on it or do you
6 get enhanced spalling in the--

7 SHOESMITH: Well, it wouldn't deal with the film issues.

8 BULLEN: I know.

9 SHOESMITH: There are measurements out there which give
10 you an acceleration factor depending on dose rate on some
11 work by George Marsh, but there are many calculations which
12 show that you suppress radically the--I didn't mean to say
13 that. There was no pun intended. You suppress the
14 concentration of radicals by a large amount by having an iron
15 2, iron 3 soluble couple because it reacts very, very
16 quickly. So, it should not be a big effect.

17 BULLEN: Was Marsh's work done in air or in aqueous
18 solutions?

19 SHOESMITH: His was done in aqueous solutions.

20 BULLEN: I guess, I would caution that you don't want to
21 dismiss it too soon until you've done the analysis in air.

22 SHOESMITH: Clarification, I don't think it's an
23 experimental need.

24 COPPERSMITH: Joe?

25 PAYER: A point of clarification. I think I heard you

1 say that it doesn't need study. I think what you meant is it
2 doesn't need--you wouldn't recommend at this time an
3 experimental program.

4 COPPERSMITH: I agree. If I had a British accent, it
5 would be a desk study, right? Isn't that what we call them?

6 SHOESMITH: I like to be an armchair scientist, but
7 really a Lazy Boy recliner scientist would be a lot better.
8 Yes, a Lazy Boy recliner study.

9 COPPERSMITH: Did you get that, Carl?

10 DI BELLA: Lazy Boy recliner.

11 COPPERSMITH: And, again, it may be one that applies
12 more to the low temperature scenarios.

13 Are there other research needs associated with this
14 type of design before we go to one where we put the corrosion
15 resistant materials on the outside?

16 SAGÜÉS: We're talking about the experiments that could
17 be generated when you have the J-13 or the repository water
18 acting on iron. And, if you may recall, you stopped the
19 discussion and we'll go the question as to whether it should
20 be a computation or whether it should be also an experimental
21 investigation of that. I think that we certainly would want
22 to recommend that an experimental investigation be conducted
23 because the computerized predictions may fail to account for
24 the most interesting species, so certainly an experimental
25 approach would--

1 COPPERSMITH: This is to whether the change in solution
2 chemistry and concentration was in the presence of carbon
3 steel in this case?

4 SAGÜÉS: Yeah. Basically, when you have dripping water
5 on the carbon steel and try to determine what kind of
6 environment is observed, and Joe mentioned the need of doing
7 that also with crushed tuff. Now, I understand that the DOE
8 is sponsoring this kind of work, but I don't know exactly to
9 which extent and to what kind of milestones are proposed for
10 that work. Could someone perhaps tell us about that?

11 COPPERSMITH: My thought is that I'd just as soon
12 identify all these research needs and then allow someone else
13 to do a mapping of what's being done or what might be done or
14 things proposed to be done as opposed to doing that now. Is
15 that okay? Because I want to be sure we get through just
16 identification of what we think those would be before we do a
17 mapping. There's plenty of people there and I'm sure that
18 people would love to jump up. Dan would love to jump up and
19 say we're doing it, dammit. But, he's not and I appreciate
20 it. So, maybe we'll forge on. And, maybe he's not doing it;
21 I don't know.

22 Anything else related to this design? Any other
23 research needs before we move on? I guess, we've talked a
24 little bit about this. From my point of view, that it isn't
25 necessarily only desk studies which would be in a large way

1 explorations of other experiments and tests that have been
2 done or, in fact, carried out tests and experiments, but also
3 maybe modeling, analysis, those types of activities are
4 something that--what I would in my mind consider to be
5 research for some of these phenomena. We do have a couple of
6 those that deal with the longer term behavior defects and
7 some of the other things that were talked about. Some of
8 those may be--to get at Digby's idea that they could be
9 determinism that relate to real physical laws, in fact, many
10 of those may be analytical types of evaluations more than
11 experiments.

12 PAYER: That's true, but the modeling activities in and
13 of themselves are not going to address this issue with
14 reliability. There's a critical need that can't be
15 overemphasized for laboratory experimental data. The area
16 has been over-modeled and under-tested to the point where you
17 cannot build credibility and reliability of the models.
18 There's all indications that they are good models, but you
19 can't test them, you can't show a duress in the environmental
20 issues and the crevice temperatures, experimental datas,
21 essentially.

22 MACDONALD: Yeah, I would agree with that, but you have
23 to be very careful to choose your experiment. You know, we
24 always think that there are a lot of bad models out there.
25 There are also a lot of bad experiments.

1 COPPERSMITH: Point well-taken.

2 MACDONALD: So, we have to be very sure that when we
3 carry out experiments that the experiments test the model in
4 a manner that conforms with the theory, with the model.

5 COPPERSMITH: Okay. Let's go on to 2 Prime which is
6 actually--remember 2 started with putting titanium bore C-22
7 over a structural material. I think the idea here is
8 potentially of having two corrosion resistant materials over
9 a structural material, but maybe there's no difference in the
10 research requirements for those. What research needs do you
11 think would be important to address that type of design?

12 KESSLER: Before we launch into the corrosion aspects of
13 it, I think it's something that was highlighted to me at
14 least yesterday that I didn't appreciate was the
15 handleability arguments or discussion that we had by Tom
16 Doering for the reasons why they liked such a thick piece of
17 carbon steel on the outside. And, perhaps, certainly that's
18 an issue. I don't know what it involved in terms of how we
19 define a research need, but when you handle something that
20 may have just a thin layer of titanium or relatively thin
21 layer of C-22 such that the C-22 layer isn't thick enough to
22 provide something you can grip and hold on to to move it
23 around. But, I don't know what that is in terms of a
24 research need.

25 COPPERSMITH: Well, I think the same thing might apply

1 to other issues related to its emplacement and contacts with
2 pedestals and so on. Is this, in fact, a fragile, delicate
3 type of surface, this corrosion resistant surface of either
4 titanium or C-22? Is it one that can be scratched, impacted?
5 I don't know. Does that damage its--

6 BULLEN: I thought the whole reason we took these
7 materials is that they passivate. So, I'd scratch it. As
8 long as it's not a gouge that's all the way through the
9 barrier, handling it is tough, it might not be as shiny as
10 the day I emplaced it, but it's going to probably not corrode
11 significantly compared after I've scratched it than when I
12 don't scratch it.

13 SHOESMITH: Well, certainly not for titanium. C-22 is--
14 most of those nickel alloys are known for having slightly
15 different surface properties depending on how they've been
16 worked or treated, but they're usually restrained to a
17 relatively thin layer at the surface. So, some of those
18 alloys, like C-276, you can see minor pitting processes that
19 go on in the surface layer.

20 BULLEN: Yeah, which you all stifle.

21 SHOESMITH: But, to mention that you're going to--unless
22 you have a serious mechanical breach, to mention that you're
23 going to change the corrosion properties by some mechanical
24 process, I don't think is a major issue. Titanium is pretty
25 close in most grades that it will be thought about a single

1 phase material. So, it's not one that suffers from depletion
2 of an alloying element. The alloys are inter-metallics which
3 are not going to redistribute.

4 COPPERSMITH: Are there other issues related to having,
5 let's say, a dual wall or mobile walls of corrosion resistant
6 material in terms of just mechanically how they're put
7 together or their influence on each other? Are those--

8 SAGÜÉS: Corrosion issues are certainly--I would think
9 that what happens at the mixed metal crevice may be a
10 question of importance because there's going to be a crevice
11 between the two things that are not going to be
12 metallurgically bonded. In that crevice, you have two
13 materials which are corrosion resistant that may interact
14 adversely with each other. Or one of them may end up being
15 the loser in a crevice situation. This may be a very long
16 crevice, meters long considerably.

17 BULLEN: Can I ask a research question associated with
18 that? Can I coextrude these materials? Do I have to have a
19 crevice? I'm asking this in a rhetorical sense.

20 SAGÜÉS: Yeah, that would be a metallurgically bonded--I
21 don't know what--

22 BULLEN: I don't know if you can or not, but that's a
23 good question to ask if you want to get rid of the crevice.
24 Let's find out a way to fabricate these things to coextrude
25 them. Particularly if you make it a smaller can, that's a

1 lot easier than doing it on a two meter diameter can.

2 PAYER: Well, explosively bonded, we looked at in a
3 number of different applications.

4 BULLEN: Yeah, but aren't there things we can do that
5 may not necessarily mitigate the issue because then you'll
6 have a galvanic couple of some type, but these are so passive
7 that--

8 PAYER: That probably complicates the welding issue.

9 BULLEN: Oh, yeah, I understand it wasn't going to be
10 easy.

11 PAYER: And, I don't know from a corrosion standpoint
12 that we worried about those crevices. Certainly, as Alberto
13 has reminded us, we have to look at those crevices in
14 experimental programs, but my feeling is that for the extreme
15 environment we're talking about now that that's not titanium,
16 C-22, or a C-22/C-22, titanium/titanium. Those crevice
17 geometries don't--I don't know of any data that scares me
18 about it right now. It has to be looked at.

19 SHOESMITH: Yeah, I think the crevice criteria for both
20 those materials are very good. Generally, if it's going to
21 be something within a crevice where you have a mixed metal
22 combination it's because you can push one of those materials
23 into a susceptibility zone. I don't think that you can do
24 that with that combination. Both these materials, assuming
25 you're not talking about Grade 2 titanium--Grade 2 would be

1 a problem--but both those materials are materials designed
2 not to propagate. I don't see how you could get the
3 potential into a susceptibility region within a crevice which
4 is not to say you shouldn't test it. I just think one could
5 be optimistic that it would not be a problem.

6 BULLEN: Do the research needs then border on whether or
7 not you can fabricate it? I mean, we might be able to have
8 the perfect unobtanium (sic) design, but if we can't build
9 it, it doesn't really matter that we've designed it and I
10 don't know about fabricability of a titanium clad C-22,
11 particularly with respect to closure, as Joe mentioned.

12 COPPERSMITH: Yeah, I think we should definitely put
13 that down. I'm not sure we have the fabricators here around
14 the table. Are there fabricators in the audience who feel
15 very uncomfortable with this type of--it doesn't look like
16 it.

17 PAYER: I would suggest just to get it on the record
18 that area of technology that could be looked at that could
19 provide some reasonable input in this area is in the coal/gas
20 scrubbers in the power industry. There's been a significant
21 use of--I believe, the term is curtain walling that are
22 large steel structures, but for corrosion protection, C-22 or
23 those types of alloys and titanium have been considered as
24 applied to those walls by different methods; by roll bonding
25 and by welding and weld overlay. I would think that would

1 give some reasonable information as to what the options are.
2 And, significant EPRI studies have been done in that area
3 over the years.

4 BULLEN: With respect to localized corrosion, are the
5 same kind of experiments we've proposed for Option Zero where
6 we're looking at ferrous chloride and concentrating of J-13
7 well water and the like just the obvious followon? Aren't
8 they the same kind of experiments you'd do anyway and
9 probably DOE is already doing?

10 PAYER: I don't see anything unique about it or anything
11 different about it.

12 COPPERSMITH: Clearly, if your drops of water, if
13 they're sizzling away, they're not on the carbon steel. Is
14 there any difference? I don't know.

15 SAGÜÉS: There's little carbon steel to worry about on
16 the outside of it anyway.

17 BULLEN: But, you're got a few ppm or the mean and nasty
18 stuff. So, you could probably concentrate to 10^6 or 10^7 , as
19 Digby mentioned, so you can get where you want to go. I
20 guess, the question is, you know, concentration of J-13 well
21 water with all the other constituents including the sulfates
22 and the carbonates and the nitrates would be the obvious
23 research need necessary for both titanium and C-22, but isn't
24 that the same as we had said for C-22 in Option Zero?

25 COPPERSMITH: Sounds like it. How about potentially

1 having these materials in contact with a lot of rock not from
2 an engineer backfill, but from drift collapse? Is that a--

3 SAGÜÉS: Yeah, that was part of the deal with water
4 chemistry, right? You could rephrase it by saying that this
5 would be the tuff metal crevice question.

6 BULLEN: Can you get to the really awful chemistries at
7 the base of the tuff metal crevice?

8 SAGÜÉS: That really should be investigated.

9 PAYER: The expectation is no, quite frankly. The
10 confirmation is what you can get.

11 COPPERSMITH: How do you do that? How do you explore
12 that crevice between the tuff--a piece of tuff against these
13 materials?

14 PAYER: For water chemistry, you take--

15 COPPERSMITH: Dave Stahl?

16 STAHL: I talked yesterday about the fiber optic probe
17 work, and one of the things that we're doing there is to look
18 at C-22 and a variety of different couples that include C-22
19 against C-22, C-22 against carbon steel, and C-22 against
20 some dielectrics, and hopefully, in that latter category, it
21 would give you some assurance that C-22 against tuff rock
22 would not give you aggressive chemistry, but that's something
23 that we're going to be determining.

24 SHOESMITH: I would suggest that it will be a good idea
25 if you're also measuring your corrosion potential, that's the

1 criteria by which we would judge susceptibility for these
2 materials. It's a very simple addition to that experiment.

3 MACDONALD: And, it's not so simple on a heated surface
4 if you're above 100 degrees and if the system is at
5 atmospheric pressure.

6 SHOESMITH: Well, that's true, but I'm assuming that
7 these tests would be done in the zone where we think this is
8 susceptible which is 100 degrees downwards. But, you're
9 right.

10 SAGÜÉS: Well, one condition also is of the area. My
11 first thinking of that would be I would get a rock sample
12 that would lop it to a very fine finish and I would put it
13 against a good hundred centimeters square of the material to
14 be evaluated and then observe visually what happens after a
15 certain amount of time; using the actual rock and not using,
16 for example, a reagent grade silican dioxide or something
17 like that. I mean, I'm just saying that the kind of things
18 which are done normally in situations like that giving it
19 every possible opportunity for it to do some mischief. Then,
20 if it doesn't do it under those conditions, then of course
21 you get--

22 KESSLER: Are you trying to prove the no hypothesis
23 though? You're doing a 100 square centimeter sample of one
24 tuff under J-13 and--

25 SAGÜÉS: Yeah, but what I'm saying is that's different

1 than getting a .1 centimeter a square of--a micro sample with
2 a microprobe method, you know, something like that.

3 STREICHER: Don't use J-13, but use other concentrated--

4 SAGÜÉS: No, concentrated, right. Right. For example,
5 I mean, needless to say, all of us have designed experiments
6 than we know what--

7 COPPERSMITH: Basically, you're trying to simulate the
8 environment of rock that has fallen off and is now in contact
9 with corrosion resistant--

10 SAGÜÉS: For example, and created a very exaggerated
11 crevice to evaluate.

12 COPPERSMITH: Okay, makes sense. So, the other issue, I
13 guess, had to do with exploring weldability with these
14 materials.

15 BULLEN: Fabricability, yeah.

16 COPPERSMITH: Fabricability. What about issues of
17 shrink-fit? We still don't know how to enter structural
18 member or a wall that potentially needs to be part of this
19 system with corrosion resistance. Is that an area of
20 research need? Is it easy to do? There seems to be somewhat
21 of a difference of opinion that I'm hearing about the
22 stresses that are associated with shrink-fit. I heard some
23 people say yesterday that those are--there will be high-
24 residual stresses associated with the process. Then, I heard
25 others say that, in fact, calculations have been done that

1 show that, in fact, there are not high-residual stresses
2 associated with the shrink-fit process.

3 SHOESMITH: Shrink-fit was an issue to Peter Andreson
4 from the stress corrosion cracking point of view and whether
5 you get the wedging stresses from carbon steel. I wouldn't
6 claim that I'm as conversant with that issue as he is, but I
7 wouldn't have thought that was as much a problem here.
8 Clearly, the wedging isn't, but I don't know whether shrink-
9 fit is as big an issue for this combination as it was for the
10 other one.

11 KESSLER: Didn't we hear yesterday again something Tom
12 Doering said that because the C-22 being on the inside would
13 be under compressive rather than tensive, that it's less of
14 an issue? I think that question that we're talking of ought
15 to be on the outside.

16 MACDONALD: On this issue, we should heed the experience
17 of the power industry in cracking the low pressure steam
18 turbine disks. There's a situation where there's a thin
19 electrolyte film on the surface caused by condensation of
20 steam, somewhat similar to what we're talking about. And
21 with shrunk on disks onto rotors, the power industry has lost
22 billions of dollars because of stress corrosion cracking.
23 So, you know, we shouldn't dismiss this, at all.

24 COPPERSMITH: Okay. One of the other issues that makes
25 this different from our #4 which has perhaps a different type

1 of structural member is that we were talking about perhaps a
2 low-cost nickel alloy is something that would be reasonable
3 for the inner wall--I'd hate to say barrier, but inner wall.
4 Is there any work or any research that would be needed
5 there? Is it just a matter of cost or making sure that it
6 meets the structural standards that are required?

7 SHOESMITH: Are we on to 4 now?

8 COPPERSMITH: Now, we're on to 2--we're still on 2
9 Prime. 4 deals with cast steel on the inside.

10 SAGÜÉS: Are we not considering that the low cost nickel
11 alloy seems to be a latter addition there?

12 COPPERSMITH: Right. That came out of the discussion.

13 SAGÜÉS: Because, I mean, why not the titanium plus C-22
14 over carbon steel? Did we move that out--

15 PARIZEK: That's on 4. That's 4.

16 COPPERSMITH: There's obviously a lot of combinations
17 with this. 4 largely is that.

18 SAGÜÉS: The use of the titanium plus C-22 together,
19 does not rule out--it would be any kind of structural
20 material, you mean?

21 COPPERSMITH: That's right. But, I want to know if this
22 is a potential either cast steel--we'll talk about that in a
23 minute--or a low-cost nickel alloy? Is there anything in
24 there that's needed in terms of any research requirement?

25 SHOESMITH: I have a real fear of having carbon steel or

1 cast steel inside this container. I think the volume
2 expansion issue potentially would open up the whole canister
3 and have a totally unpredictable situation within the
4 canister once you fail. I don't know how you go on to model
5 the next stage.

6 BULLEN: I have a question about your low-cost nickel
7 alloy. Do you want to specify? Do you want a Monel 400? Do
8 you want to go to a CDA-715?

9 SHOESMITH: Well, I think the criteria for that--for a
10 low-cost material on the inside are malleable in the sense
11 that Michael brought up an objection to 825 based on the
12 copper content. There's a whole suite of materials in that
13 range which if you have got the C-22 over titanium to bring
14 the temperatures down to, I don't know, 30 or 40 degrees
15 because you've lasted 10,000 or 20,000 years on the outside,
16 now a whole range of materials are available from which you
17 can choose those which you like structurally and those which
18 don't contain the alloying elements that you were concerned
19 about. So, I don't know that--I don't feel comfortable to
20 specify what a material would be, but a metallurgist would be
21 able to address that question. That's the philosophy behind
22 that suggested design.

23 COPPERSMITH: Is there any other research needs that
24 people could identify for that design?

25 SAGÜÉS: For the outside, that would affect possibly 2

1 Prime and 4 and 6. There's a question of the supports which
2 we have mentioned before. It should be evaluated as to
3 whether the contact at the bottom of the container and the
4 pedestal could introduce unforeseen problems that are not so
5 important in Option Zero.

6 COPPERSMITH: Is this something that we think would be
7 addressed experimentally or--

8 SAGÜÉS: It probably could be addressed as part of the--

9 BULLEN: 2 Prime coupled research?

10 SAGÜÉS: Yeah, of the crevice questions.

11 COPPERSMITH: I imagine those pedestals--what is it,
12 three or four per canister? I think they must have three--
13 two to three per canister? Must have some pretty and
14 relatively small contact point. Must have some very
15 stringent strength requirements, I would imagine. It may
16 limit the materials that's used for that.

17 MACDONALD: The AECL design--not the AECL, Ontario
18 Hydrade design has the canister backfilled with glass beads.

19 SHOESMITH: One design, yes.

20 MACDONALD: And, is there a plan to do that similar
21 thing in this case or is it just inert gas?

22 SHOESMITH: I don't believe so.

23 MACDONALD: Why not do that to provide additional
24 structural integrity? Put a borosilicate glass in there and
25 deal with the criticality issue, as well.

1 COPPERSMITH: Well, I guess--I don't know. Number one,
2 I think that some of those structural integrity loads that
3 are needed in the Canadian situation exceed those here
4 related to glacial loading and some other criteria.

5 SHOESMITH: Well, the glass beads wouldn't get you
6 through glacial loading, but the reason for introducing an
7 internal support is the hydrostatic, lithostatic pressures
8 that you get below the water table in the presence of a
9 compressing bentonite, but it does give you structural
10 support. It's the same philosophy.

11 COPPERSMITH: I don't know if someone wants to speak to
12 that need for structural support. Has there been thought
13 given to that concept or is it basically the wall--I've
14 always been assuming that the wall handles the--

15 DOERING: From the packages that we have on the boards,
16 both the small and the larger packages, we have liquid filler
17 material of an iron shot trying to see if we can get it in
18 and the answer is, yes, we could get it in. Now, that would
19 be for two basic reasons that we're looking for. One is to
20 maybe buffer the material on the inside if we had some
21 radionuclide release. And, secondly, it would also be a
22 moderator displacement so you minimize the criticality
23 scenarios. Looking at it from a structural point of view, we
24 haven't done that yet. We know it does add weight to the
25 overall system. Essentially, what we're saying looking at

1 there, if it does add weight to it, then the overall
2 structure has to get heavier and thicker to handle that
3 weight. So, again, it's things that can be done, but you
4 have to balance them off against--you know, there's things
5 that come along with that design.

6 We did look at the borosilicate glass at one time
7 to see if that would be a positive thing for criticality
8 control. That is doable. Once again, we have shown we can
9 get it in, but the question is we don't have a hydrostatic
10 pressure to deal with. And so, the driving force for that
11 design option really isn't there for our particular site.

12 COPPERSMITH: How about volume expansions? There's a
13 lot of pore space within the present design. I thought that
14 was due to anticipated volume expansion of basket materials
15 and other internals. Is that correct?

16 DOERING: Actually, the designs that we have chosen, the
17 21 and a 12 pressurized water reactor and 44 and 24 BWR
18 reactor, minimize the internal void space. It's one of the
19 designs--

20 COPPERSMITH: What is it? Is it 30 percent or
21 something--

22 DOERING: Oh, no, no, it's much less than that. I don't
23 know the number specifically, but it's something we can get.
24 We have those. We do have curves and that sort of thing.
25 David did mention one thing is that the glass and also if we

1 do other materials inside there, do degrade relatively
2 quickly and he mentioned that. So, we do have to take a look
3 at how that internal corrosion would now occur. Then, if we
4 do get the iron shot, if that iron shot again grows, it does
5 have a positive statement of criticality minimization.

6 KESSLER: But, you haven't looked at that yet?

7 DOERING: We haven't looked in that detail of that.
8 It's an option that we're leaving available if we need to go
9 to it. Again, for our site, it's not as needed. So, it
10 hasn't been, you know, adopted. It has not been incorporated
11 into the baseline design.

12 KESSLER: While we're talking about all kinds of
13 fillers, have you taken on the depleted uranium issue?

14 DOERING: We have looked at the depleted uranium. We
15 have looked and seen how we can get it in. If we can get
16 into the same spherical configuration as the iron shot that
17 we have because that was an easy way to do tests, we could
18 get it in. The question there is how much do you need, and
19 for commercial spent nuclear fuel, for criticality control
20 and issues, it's a no starter. We don't need it. There are
21 other ways of handling the criticality control issues.
22 Again, if you use the depleted uranium, all you're doing
23 really then is making the system heavier, and in a corrosive
24 environment, depleted uranium is not very good in a corrosive
25 environment. Also, it actually accelerates the corrosion.

1 So, from those two points of view, we didn't feel it was
2 necessary for commercial spent fuel.

3 Truly, maybe for some highly enriched material,
4 99%, if we could dilute it to bring it down to 20%, we are
5 looking at that and that's more of the defense waste, not the
6 commercial waste. Also, the significance to handling. If
7 you put it in small package or a large package, you have to
8 take a look at the surface facility of where you put the
9 material in. Now, it's heavier and now the material input is
10 more difficult also. So, it does complicate the process and
11 makes the package heavier.

12 PAYER: I would suggest that it's a parking lot issue
13 for our scope here. The whole area of fillers, I mean, it's
14 an important area and that's useful insight, but--

15 COPPERSMITH: Are there any fillers that have been
16 proposed that actually help waste package performance
17 significantly?

18 PAYER: Well, I think our focus here and I think it's
19 the right focus is on avoiding penetrations, period, and not
20 so much getting into the issue of what happens once you get
21 penetrations because that's another whole different ball game
22 and tremendous uncertainties. Very important issues, but a
23 different twist, I believe.

24 COPPERSMITH: Tom, did you have another?

25 DOERING: Just one comment. Back on the--I think, Dan

1 when you came to take a look at us back in April, we did have
2 a slide in your package that showed the waste package
3 configuration efficiencies that we had. And, also, the 12
4 PWR essentially has on the order of, let's see, .11 cubic
5 meter of sort of void space inside of it. That's a 12. And,
6 the 21 is more close to .1 cubic meter empty space inside of
7 it which are the two most efficient packing densities on this
8 curve. So we have taken that into consideration.

9 COPPERSMITH: Before we go on to the next one--I know
10 that David is ready to cast dispersions on internal steel;
11 I'm anxious to hear it--anything else up here on this type of
12 design?

13 SHOESMITH: 2 and 2 Prime deal only with titanium over
14 C-22. There was a discussion of whether we should have C-22
15 over titanium. Is that a--

16 COPPERSMITH: Is there a difference in what would need
17 to be looked into for that type of design?

18 SHOESMITH: Well, most issues are the same except it
19 brings up one issue which I feel is not addressed which is
20 residual water within the container. Titanium potentially,
21 for a hot vapor atmosphere, could soak up hydrogen on the
22 inside. But then, the issue arises for all the other
23 materials like what would the radiolysis problem be for C-22
24 if there's residual water? Is this a limited--do we know how
25 little water there's going to be in here? Is there a

1 criteria? Are we expecting a lot, a little?

2 COPPERSMITH: This was prior to breach within the waste
3 package, is that what you're asking?

4 SHOESMITH: Yes. Yeah, how much residual moisture will
5 there be in there because all of these materials would then
6 suffer a hot vapor--on the inside and it might be worse for
7 titanium on the inside than for the others.

8 COPPERSMITH: Well, maybe that's an issue then that
9 would--

10 SHOESMITH: But, if somebody tells me there's no water
11 in these things and they can guarantee it, then it's not an
12 issue.

13 KESSLER: Is another potential benefit of putting the
14 titanium on the inside that you don't need so much of it?

15 SHOESMITH: That's another possibility plus you don't
16 need such a high grade because your temperature is almost
17 certainly below 70 degrees. So, the commercial grade is
18 acceptable. The cost of the material itself drops a factor
19 of two to three.

20 COPPERSMITH: Okay. Shall we go on to Design 4 which is
21 corrosion resistant material, C-22 over cast steel? Who is
22 the proponent for this?

23 BULLEN: I am.

24 COPPERSMITH: What would you like to have studied to
25 verify?

1 BULLEN: I guess the concern that was raised by both
2 Digby and David was that corroding of the steel on the
3 internals of corrosion resistant barrier on the outside has
4 the potential for volume expansion significant enough to
5 fracture the container. Is that a reasonable--that was Joe,
6 okay. Well, I'll cast blame on Joe, then. I'm interested in
7 sort of the mechanisms of corrosion and I guess it was
8 mentioned that you wouldn't have--if you had a pitting
9 failure of the C-22 and you wanted to take a look at what
10 happens underneath to the carbon steel or cast steel, you
11 would expect basically that the water ingress is going to be
12 the limiting step. As long as you've got water coming in,
13 you're going to continue to have oxidation and so you're
14 going to continue to have rusting. Would you limit the
15 amount of water by packing it off with corrosion product or
16 is that going to still drip in there forever? Don't know?

17 PAYER: It's not going to stop water ingress. It could
18 slow it down. It won't stop it. Trying to come up with an
19 analyzable description of how much water entry through
20 corrosion penetrations is a difficult task and I don't know
21 that quick experiments or even slow experiments are going to
22 shed a lot of light on that.

23 MACDONALD: A good illustration of this phenomenon is
24 the paint on your automobile. If you have a little stone
25 damage, you find that the paint swells, lifts off the

1 surface, and that's because of the formation of iron oxide
2 underneath the paint. That's the basic phenomena. But, Joe
3 mentioned the phenomenon of denting in nuclear steam
4 generators which pretty well killed one type of steam
5 generator and this was a case where people had not
6 anticipated (a) the rate at which magnetite would form and
7 (b) the forces, the enormous forces, that crystalline
8 magnetite growing in the crevice could exert on the tubes.
9 They literally crushed the tubes, the Inconel 600 tubes.
10 And, that's where the name denting came from.

11 STREICHER: Carbon steel tube sheet?

12 MACDONALD: Yeah, from the carbon steel support plate.

13 PAYER: And, that was a very dense magnetite and yet
14 there was sufficient transmission of water to keep that
15 process going. And, the experience is on just many steel
16 structures that if water gets in between into a crevice or
17 joints or riveted joints and things of that sort and
18 corrosion starts there, it doesn't stifle itself by the
19 corrosion products being so dense and so non-porous that it's
20 just not observed. So, the rates of water coming in are not
21 known very well, but I think it's not a defensible argument
22 to say that those corrosion products will be self-stifling.

23 MACDONALD: Right. And, one element that exacerbated
24 the whole process is copper. Getting to Mike's comment, you
25 don't want copper near carbon steel.

1 STREICHER: Well, they were saving money, right, to use
2 carbon steel instead of the same alloy as the tubes?

3 MACDONALD: Oh, yeah. Yeah. They thought they were
4 saving money.

5 COPPERSMITH: Getting back to this issue of--and, I'm
6 not sure; this might be parking lot, it might be something
7 that really needs to be looked at. The whole issue of if
8 you're going to use--well, maybe for any type of alloy, but
9 particularly if it's going to be carbon steel involved, this
10 issue of the corrosion products and whether or not, in fact,
11 they serve to either stifle additional corrosion or some sort
12 of transport barrier continues to come up. I'm not sure if
13 there are ways--if it's important enough or if there are ways
14 to address that issue of the effect of corrosion products.

15 MACDONALD: For most metals, at least the first row
16 transition metals like iron, nickel, cobalt and so forth,
17 passivity is conferred onto the system by the barrier layer,
18 not the outer layer. The only class of metals where you get
19 protection because of the alpha layer that's a precipitated
20 layer of corrosion product is in the valve metals. Titanium
21 happens to be one of them. Aluminum, for example, you know,
22 the favorite trick for enhancing the corrosion resistance of
23 aluminum is to boil it in water. What you do when you boil
24 it in water is that you seal the alpha layer.

25 STREICHER: You swell the oxide.

1 MACDONALD: Right, yeah, and because of the
2 recrystallization process and it seals the outer layer in
3 which case you have an additional barrier between the metal
4 and the environment. But for, you know, metals that are
5 based on nickel, cobalt, iron, and so forth, you cannot in my
6 opinion take any credit for the alpha layer and you've got to
7 appeal to the barrier layer as the mechanism of corrosion
8 protection.

9 PAYER: I would suggest that that topic and treatment be
10 similar to what was suggested for radiolysis. That a lot
11 could be gained from existing information that needs to be
12 pulled together and analyzed with respect to this
13 application. Perhaps, the amount of experimental work that's
14 doable or needs to be done is not very great. But, until you
15 do that first part, I'm not sure that--

16 COPPERSMITH: Did you get that, Carl?

17 MACDONALD: I think I would caution against that because
18 most of the experimental work that's been done on passivity
19 has been short-term.

20 KESSLER: Yeah, but I would argue that given the time
21 frames we're considering for Yucca Mountain if they're shown
22 to be unimportant over the short-term, they're certainly
23 going to be unimportant over the long-term; the near layers
24 as opposed to passive layer. If you talk about whether the
25 passive layer controls things, then it's an issue. If you

1 can transmit through these corrosion layers the reactants and
2 products that you need to get in and get out over short-term
3 experiments, over the long-term, they can--

4 MACDONALD: You could argue both ways. I mean, you
5 could argue that over the long-term, in the case of the first
6 row transition metals, the outer layer will eventually
7 through crystallization processes become protected. On the
8 other hand, you could argue that in the case of titanium, you
9 know, that the outer layer because of the stresses that are
10 built in between the inner and outer layers that will
11 eventually crack and fall off and--and, you know, there is
12 some evidence that fully under the--in the zirconium case,
13 for example, where you can grow films relatively quickly in
14 high temperature water, the stuff goes through a series of
15 transience resulting in spalling of the oxide.

16 SAGÜÉS: I wanted to bring up we're talking about the
17 corrosion of the internal carbon steel or cast iron or
18 whatever would be there. There is a couple of answers.
19 First of all, in here, we can have some alleged cathodic
20 aggravation of the corrosion of the material inside because,
21 of course, there's going to be a reasonable variance with
22 more metal around--

23 And, the other thing is that it seems there is a
24 lot of time comparatively speaking for this phenomenon to
25 take place. Even if one could have a fairly protective plug

1 in the hole, still there is a lot of time for this process to
2 continue, okay, for 100 years, it would be fair to say--1,000
3 years, for example. So, I think that those are things that
4 conspire to make this a potentially severe problem along the
5 lines of what Joe and Dave were saying.

6 I guess, this goes back to what we were saying
7 before. If one is going to use cast iron, I think that one
8 probably should assume that the worst is going to happen and
9 that there is going to be very little time comparatively
10 speaking to failure from the moment in which the external
11 corrosion resistant layer is breached until the thing begins
12 to have a good chance of bursting open.

13 COPPERSMITH: Well, I guess, that potentially is the
14 problem with that Design 4, then. Once you lose that CRM,
15 other things, as you say, conspire to happen more quickly.
16 Maybe, the expansion issue, those types of mechanical type
17 failure, as well as other things, may lead to a more early
18 failure after that first breach.

19 SAGÜÉS: And, I was going to say perhaps we should go
20 into something a little bit simpler or a little bit more--if
21 we replace that, for example, with some inexpensive stainless
22 steel like, say, 304 or whatever, would we be any better?

23 BULLEN: I was actually going to say that we probably
24 already addressed this with respect to 2 Prime; taking a look
25 at a different structural component on the inside. We've

1 sort of beat the dead horse with respect to either the carbon
2 steel or a cast steel on the interior and it's probably not a
3 good idea. Having documented that, we could probably just
4 move on.

5 SAGÜÉS: Okay. Suppose we say that we go with 316 or
6 304, something that would cost, say, \$2 a pound, and it has
7 to be, say, about the same kind of strength that was obtained
8 with that. Now, the C-22 costs, I understand, something like
9 about \$10 a pound or so. So, now, they're making this, say,
10 four inches--or 10 centimeters of 304 inside is the same as
11 basically putting an extra two centimeters of C-22 or
12 something expensive like that.

13 BULLEN: Right.

14 SAGÜÉS: Would that take this concept then into a cost
15 that would be remarkably superior, remarkably greater than
16 what one would get in Design Zero? And, will it be
17 worthwhile to do that considering that one gets presumably
18 much greater benefit by having removed all that carbon steel
19 from that site?

20 KESSLER: Well, if you go back and couch it in terms of
21 what Joe did this morning, would it be worthwhile, of course,
22 that makes me nervous to think about that again. But, if it
23 lasts long enough to get through that 105 to 80 C range,
24 maybe that's a criterion that we can use at least at this
25 table.

1 BULLEN: Did you put the stainless steel on the outside
2 or the inside?

3 SAGÜÉS: Inside.

4 BULLEN: It's the same thing as 2 Prime where you've
5 gotten through the temperature regime, but you're looking at
6 something that--I don't know, 304 and 316 was--you know, how
7 much more do you spend to get to 825 if you're going to do
8 it--I mean, which is the same question we have in 2 Prime or
9 to some other low grade nickel alloy without copper. We'll
10 leave the copper out just for Michael's point of view here.
11 But, I mean, from that perspective, I can see then you should
12 probably not use the galvanic couple or inverse galvanic
13 couple of C-22 over steel. If you're going to replace it
14 with something else, then you're just back up to 2 Prime
15 again, aren't you?

16 SHOESMITH: I'd say the difference here is whether we're
17 contemplating using a corrosion allowance material on the
18 inside or a second corrosion resistant material no matter how
19 poor a grade of corrosion resistant material it is. This
20 volume expansion and pressuring, wedging effect is a
21 corrosion allowance material problem. If you go with a
22 second corrosion resistant material, then you would believe
23 that the propagation of the corrosion will be relatively
24 uniform. The film is on the outside. It's probably going to
25 fall off. You won't get this very rapid acceleration of the

1 overall corrosion when you hit this barrier, when you hit
2 this crevice between the two. So, I think, that's all the
3 difference is.

4 SAGÜÉS: But, is it worth it to double the cost of the
5 container by doing that basically?

6 BULLEN: I guess, that's the whole point of going with
7 something that's cast is if you're not talking about it as a
8 barrier and we're looking at both dissolution of the C-22
9 where we finally got it to fail, then you're out at the 10⁵
10 or higher years. So, the issue is actually from a
11 performance assessment point of view what's the failure of
12 distribution of the containers as opposed to a step function
13 failure which is really not what you'd want. And so, I'm not
14 sure that any--obviously, in the case of 4, the only barrier
15 you've got is C-22. The other one is not a barrier; it's a
16 structural component, period. And, is that a big enough
17 detriment that you don't want to use cast steel as the
18 interior component because of the fact that if you did have a
19 pinhole failure, you would essentially give the opportunity
20 to split open a container with the swelling of the
21 components. And, I think that's probably an issue not to
22 have documented in this forum and then just leave it at that.

23 COPPERSMITH: Pros and cons of each design. Some people
24 have asked us is when are you guys going to have a panel to
25 rank these? I think, number one, they are sufficiently

1 fluid, even as we talk right here, let's move this out, let's
2 do this, but they're not, in fact, discreet design
3 alternatives. Number two, I think the idea is are there
4 research needs that would go across the board here that we
5 could think about giving a sort of a range of possibilities
6 that we're dealing with. So, I think that's more important
7 right now is those research needs.

8 BULLEN: Contrary to what it appears, we're not here to
9 redesign the container; we're here to provide information.

10 COPPERSMITH: Looks like you're doing that, right?

11 BULLEN: Even as I speak, it looks like I'm doing that.
12 But, what I'm trying to do is get a feel from the experts
13 what are the issues that should be evaluated in the
14 alternative design--

15 COPPERSMITH: What should be looked at.

16 BULLEN: Right, what needs to be looked at and what kind
17 of advice or guidance or comments will the NWTRB make to the
18 DOE--actually, to the Secretary of Energy and the Congress
19 when we get to a point where we have to respond to issues
20 like VA and LA. So, this is just laying a basis, a
21 groundwork, that the Board can refer to that say, yeah, we've
22 had experts look at these issues and these are things that
23 are good and these are things that are not good. But, we
24 don't want to rank it and we don't want to have a new design
25 based on what comes out of here.

1 COPPERSMITH: I met Dan Bullen about five years ago on
2 the EPRI study in the days of Bob Shaw, the early TSPA that
3 EPRI decided to do. I remember coming in there and I was on
4 seismicity and things like that and I said, well, this is
5 what the earth does. Then, we came to Dan and he said, well,
6 in my case, I can do anything. It's just a function of
7 money. If you want a million year canister, just give me the
8 money. If you want a thousand year, give me less money. I
9 thought that was a pretty interesting scale and I guess it
10 doesn't change.

11 BULLEN: No, and with respect to you there, Kevin, it
12 was almost nine years ago. Isn't that terrible?

13 COPPERSMITH: It's horrible. I don't want to think
14 about it.

15 BULLEN: I know.

16 COPPERSMITH: Another issue here that I think crosses a
17 lot of these designs, we're going to--at some point here,
18 we're going to stop and allow an opportunity for comments
19 from the public, but I think an issue that to me is not
20 clear, the public is not geologists, the whole issue of wall
21 thickness--I mean, ultimately, we're not designing these down
22 to where we're going to have a centimeter of this and a
23 millimeter of that and eight centimeters of this, but is, in
24 fact, wall thickness for corrosion resistant materials, is
25 that a thought? Because what we're dealing with here is

1 we're dealing with whether or not you're slightly into and
2 out of a window susceptibility vis-a-vis localized attack.
3 The idea is to try to stay out of its windows of
4 susceptibility. But, let's say you get in it, and when
5 you're in it, does the wall thickness do anything for you?
6 And, I think, the thought is, yeah, it takes longer to go
7 through four centimeters than it does to go through a
8 millimeter. But, how important is that is an area to really
9 think about. Is it really--you know, John Scully, for
10 example, says, hey, keep me out of the windows because once I
11 get you in a window, I'm going to slice through every alloy
12 you've got like a knife through hot butter. And, it
13 basically is very, very quick; therefore, wall thickness
14 doesn't do much for you if, in fact, you get into those
15 windows.

16 SHOESMITH: It depends a lot on what kind of process
17 you're looking at. If you have a linear growth model at a
18 very slow rate, then within reason, I mean, one millimeter is
19 ridiculous, but within reason--

20 COPPERSMITH: One centimeter versus five or something.

21 SHOESMITH: But, if you have a growth law which is local
22 which is rapid initially and then for one reason or another
23 turns over, then there is indeed an allowance--minimum
24 allowance in order to get you through that fast initial
25 period. So, it depends a lot on what process is going to

1 fail you. If it's a stress corrosion crack, it's probably
2 immaterial. I mean, this is rapid failure. So, generally,
3 it's not a huge factor. It's a factor when you want to limit
4 a localized corrosion process by one of those growth laws
5 with a T to the n where n is less than one.

6 COPPERSMITH: And, how appropriate are those? Is this
7 an area of research that we look into? For example, titanium
8 and C-22, the nature of those growth laws, is that doable?

9 SHOESMITH: Oh, I think it's doable, yeah. It's doable.
10 We did it for Grade 2 titanium. We did it for Grade 12
11 titanium. There are, at least, another seven or eight more
12 detailed studies than ours out there where people have looked
13 at those kind of growth laws.

14 COPPERSMITH: And, T to the n where n is less than one?

15 SHOESMITH: Yeah, predominately. Natural carbon steel
16 corrosion in soil, n is between .2 and .4. You know, it's a
17 heavily stifled process thanks to Dan's analysis.

18 SAGÜÉS: There is another factor for wall thickness
19 which is the presence of likely flaws in any manufacturing
20 process. And, you want to have a wall thickness that would
21 be a certain multiple of the largest possible flaw. And
22 then, there is the other question on stress corrosion
23 cracking. If you go to extremely small wall thicknesses,
24 then you have to look at what would be the largest size of
25 those potential problems. So, I think that you cannot talk

1 about a 1/2 millimeter type of wall thickness. So, there
2 must be some other limits.

3 COPPERSMITH: Again, I haven't seen the results that
4 have come out of the TSPA/VA yet, but all the experts on the
5 panel--on the Waste Package Degradation Panel gave estimates
6 of n values for localized attack of C-22 and I suspect that
7 the n-value of that T to the n distribution is going to be a
8 very important parameter given you're in the window. But, is
9 it worthy of study? I think the things that Joe laid out in
10 my mind deal with the likelihood of being in the window or
11 not and those are very important.

12 SHOESMITH: On the table are the suggestions that you
13 had to deal with whether you could stifle C-22. You had to
14 demonstrate that it would repassivate. As part of that
15 study, one way or another, you would demonstrate that the
16 repassivation would occur after a certain amount of damage
17 which would be related to a depth of penetration. So, you
18 would effectively be saying if it stifles completely for a
19 small amount of damage and effectively goes to zero. So, you
20 aren't dealing with the same kind of growth law; you're just
21 dealing with one extreme where anything approaching zero as
22 opposed to the other extreme wherein it's hitting one. So,
23 it is part of that philosophy.

24 COPPERSMITH: Exactly. And, for example, the same
25 thing, it seems to me with passive dissolution or let's say

1 passive corrosion is it's a very low value. Rate is very
2 low. TSPA goes out hundreds of thousands of years and, all
3 of a sudden, the n-value of passive dissolution law becomes
4 an important characteristic. So, it seems to me that those
5 are potential areas that might be important from a PA point
6 of view, but I'm not sure if they're viewed as even
7 researchable in the sense of, say, for C-22 we're going to
8 give a better feel for the actual growth law for localized
9 corrosion of C-22. Is that something that could be done in a
10 reasonable period of time? I understand electrochemical
11 tests and the potential tests that could be done to deal with
12 the issue of moving into your T-crevice and so on, but given
13 you're in there, can you stay there?

14 PAYER: I think it could be addressed, but I think it
15 has to be a significantly lower priority than the issues that
16 we've already identified. At this point, I think it would be
17 a distraction.

18 COPPERSMITH: Okay.

19 PAYER: I think you could again deal with it from a--

20 COPPERSMITH: Is that because you think it will happen--
21 if it locally corrodes, it's a process that just happens very
22 quickly and therefore there's no credit to be taken from the
23 process?

24 PAYER: On both extremes. I think if you can come up
25 with a realistic environment that will get the localized

1 corrosion going and sustain it over a period of time, you
2 lose with that material, that combination. The arguments are
3 going to be more along the lines of how often do you get the
4 amount of moisture required at that location to get into it?
5 That's going to be the issue, not once the conditions are
6 there. An example, a stress corrosion cracking of buried
7 pipelines; typically, these are steel pipelines. They're on
8 the order of a half inch thick buried in the ground. Typical
9 failure times of that are 14 years, 20 years from the time
10 they're buried in the ground. In the laboratory, if you
11 create and sustain the conditions to corrode those stress
12 corrosion cracks, you go through that half inch wall in a
13 matter of days. What that tells you is that the crack growth
14 rate when it's going is quite high, but it isn't going very
15 often out in the real world due to the environment and so on
16 and so forth.

17 SHOESMITH: Yeah, I'm not as willing to dismiss this
18 kind of study. I think these passive materials are designed
19 very specifically to stop the process occurring, not to stop
20 it initiating. If you look at corrosion potential
21 measurements on a crevice--we haven't done this for C-22, but
22 we've done it for the 276--you'll see it make many attempts
23 to start crevice corroding, but you'll also see them
24 disappear. If you are simultaneously monitoring a current,
25 now you have a measure of the damage that you're accumulating

1 plus a time signature of whether this material is giving you
2 any penetration or not. It's giving you an interval of how
3 many of these--it's giving you a count of number of events
4 that are attempted. It's giving you the duration of these
5 events and they change with temperature and environment.
6 It's giving you a measure of whether this material is
7 attempting or not--this would be called metastable pitting if
8 it was a pitting experiment below the susceptibility
9 potential--I would suggest that those kind of experiments
10 followed by a metallographic examination to see how deep you
11 went are probably in the longer term a much better guarantee
12 if you want to say this material will not go. Because now
13 you're seen it try and it can't as opposed to having asked
14 the question will you or will you not get into the window of
15 susceptibility and then you argue about how long do you have
16 to wait before you're in there. So, I wouldn't dismiss that
17 kind of study. I think it's essential for C-22.

18 COPPERSMITH: Okay. Hold that thought. Alberto is
19 going to take over.

20 SAGÜÉS: We are now in the public comments coming from
21 the public section. I would like to invite those present who
22 would like to make some comments on the material we have
23 discussed this morning.

24 CRAGNOLINO: Gustavo Cragnolino, Center for Nuclear
25 Waste Regulatory Analyses.

1 I'd like to concentrate especially in this idea for
2 the corrosion resistant material. I'd like to support what
3 was mentioned by Joe Payer because it's very consistent
4 regarding the choice of material that we have been using for
5 several years in our projects. That mean is a criteria of
6 using some critical parameter to assist the possibility of
7 repassivation once localized corrosion is initiated for this
8 material. This is precisely the case of 825. We tried to
9 extend this approach in a limited fashion to 625 and C-22,
10 and I think that there is a valuable expedience to correlate
11 these repassivation potential with critical temperature
12 because you define this in an envelope that combines
13 environmental factors and the potential oxidizing force, and
14 one important environmental factor is the temperature. You
15 can vote either way, to use the critical potential for
16 repassivation and compare this potential with the corrosion
17 potential or when you are using a system without the use of a
18 potential start you can use the temperature as a criteria
19 once the environment is defined. I caution, however, that in
20 the case of C-22, we may have to go to extreme situation in
21 order to have this critical temperature. I would have to be
22 able to extrapolate down and locate this range of this
23 activity.

24 I want to complement the approach that has been
25 used by the Canadians in the case of titanium that you can

1 also measure the evolution of this by simple techniques and
2 will lead to the same conclusion.

3 The other point is regarding the passive covering
4 or whatever we call these low corrosion rates. I believe
5 that it's a pretty difficult to measure and now we are moving
6 in the direction of a very low corrosion rate that may change
7 the life of a material in tens of thousands of years. And I
8 think that here have to be a combined effort in terms of
9 using modeling, much more concentrated modeling effort, and
10 specific techniques like the quartz electrobalance, I think
11 we mentioned, to make a correlation between the short term
12 possibility of doing experiments with the approach in order
13 to predict this. And, be confident that we can define at
14 least a threshold value that will be a way to indicate a
15 minimum lifetime for this corrosion resistant material. I
16 think that this will be an approach that will be defensible
17 from the point of view of the viability assessment first and
18 the license, at least for the corrosion material.

19 I don't want to deal with the comments about the
20 specific form of a design because it's out of the scope of
21 the approach that we have taken and I think that this is a
22 decision of the Department of Energy. And in our program in
23 support of NRC, we never have made any commitment at this
24 time, but we tried to have a methodology approach to deal
25 with this type of issue.

1 SAGÜÉS: Well, thank you. Do we have any response on
2 the part of the Panel participants before we have the next
3 speaker?

4 (No response.)

5 SAGÜÉS: Okay. So, please, identify yourself?

6 HARRINGTON: Paul Harrington, Department of Energy. As
7 all of you do, we have to prioritize our work. We have
8 limited funding and time resources. It would be very helpful
9 for us in doing that to get some sense from you of relative
10 priorities, not just the performance of the individual
11 approaches up there, but also how they perform relative to
12 the existing package. We're going to have to follow on to
13 this. We need to know where we need to put our resources.

14 Thank you.

15 SAGÜÉS: Thank you. Any response to this?

16 (No response.)

17 SAGÜÉS: How about any other comments? Yes, sir, please
18 identify yourself?

19 MOELLER: My name is Ralph Moeller representing the
20 Nickel Development Institute. First of all, the Nickel
21 Development Institute is very interested in this project
22 because it uses nickel and that's our purpose in life. I
23 want you to use a lot of it.

24 You may be aware that we sponsored two different
25 workshops on this subject. The first one was in '94 in

1 February where we discussed general metallurgy and the major
2 nickel producers in the world were there and told everybody
3 about the new alloys that existed. I'd like to think that
4 out of that meeting came the idea to use a higher alloy than
5 825 and they went to 625 and then to C-22. In March of this
6 year, we had a second workshop dedicated to the long-term
7 phase stability of Alloy C-22 where C-22, 625, C-276, and 825
8 were all discussed.

9 I came here with the intent to listen very closely
10 to see if there's any area that the Nickel Development
11 Institute can get involved in. Not that we've got money that
12 we want to give away, but we are pretty good at facilitating
13 and putting the right people together to discuss things. It
14 occurs to me that maybe fabricability is the next thing that
15 we should consider. It disturbs me a little bit that you can
16 sit around this table and talk about the alloys and which way
17 you're going to flip-flop. I know you talk about the
18 fabricability of it. Dr. Payer brought it up earlier today
19 and talked about flu-gas desulfurization where we can get a
20 great deal of data where they do wallpapering which they
21 started out with Alloy 625 and then changed to C-276. But,
22 there's a lot of data available and a lot of pictures, a lot
23 of photo micrographs, a whole lot of data.

24 I would like, if you would allow me, to take one
25 minute to tell you what my approach would be to this vessel.

1 Could you put that last viewgraph up, please? I've heard
2 you discuss Zero and I've heard you discuss 3 and the
3 problems with it. David Shoesmith pointed out that if you
4 have C-22 over carbon steel, you will have a corrosion
5 product so great that it could crush the C-22 canister.

6 I'd like for you to consider combining Zero and 3.
7 Have the carbon steel over to C-22, but have s C-22 over the
8 carbon steel. Have you thought about taking a clad steel as
9 your outer barrier so that your water then drips on C-22, but
10 the C-22 is not very thick, eighth of an inch perhaps. And,
11 it's metallurgically bonded. So, hopefully, the
12 metallurgical bond would eliminate the problem of the
13 corrosion product bursting. You wouldn't need such thick
14 carbon steel then because you won't use it, at all, as a
15 corrosion barrier. You use it as a strength barrier. And,
16 since it's there and the C-22 is so thin on the outside, the
17 C-22 isn't supporting all the weight when you lift it and
18 shift it and do all that other stuff; the carbon steel is.
19 And, yet, if you ever get through that, then you still have
20 the corrosion resistant material on the inside whether it be
21 C-22 or Carpenter 20 or whatever.

22 That's my only comment on that, but I would like to
23 make one or two or three just real quick comments. You were
24 talking about the possibility of stress relieving or post-
25 weld heat treatment. That doesn't necessarily have to be as

1 high as 1100 Centigrade. It could be 1,000.

2 I was supposed to speak a little bit on relative
3 cost. Alloy 825 is about half the cost of Alloy C-22. If
4 you buy it today, 825 would be about \$4 a pound; your C-22
5 would be \$8 to \$8.50. But, that's not what it's going to be
6 when you buy it. The reason is is because if you play your
7 cards right and write your specification correctly--and it's
8 very important to write your specification correctly so that
9 anybody can manufacture this material that's in the business
10 --then, you will dictate the price. It won't be \$8 or \$12,
11 whatever it might come up at that time; it will be what that
12 person is willing to sell it to you to get that amount of
13 business. They are really going to want that business unless
14 there's some other great big project coming on at the same
15 time. If you hit them all at once, that would be a law of
16 supply of demand and you had wanted more than they wanted and
17 say the price would be way high, but if you play your cards
18 right and you spread it out so that you just kind of fill up
19 these mills all the time, you could have a really good price.
20 So, I think that's a very important thing to consider.

21 Thank you.

22 PAYER: Ralph, did you have quality assurance costs
23 built into that pricing?

24 MOELLER: Yeah. You'll find out that most of your high
25 nickel alloy producers today manufacture every pound of

1 product they do as if it were going in a nuclear reactor.

2 They can't afford to do anything else.

3 SAGÜÉS: Yeah, I have a question concerning that. That
4 is we have--when Gustavo spoke at the beginning, he
5 mentioned, well, we should look at the extreme conditions
6 that will result on the highest potential or the highest
7 chloride content and so on. We should also look at the
8 extreme weaknesses in the metallurgical stock we're dealing
9 with. So, we want to make sure that we are not concentrating
10 so much in chemistry evaluations; we have to also concentrate
11 or look at very much as to what would be the levels that
12 affect the off spec spots and so on that may exist in the
13 material. And, that can have a very significant effect, as
14 well. Again, your quality assurance for that will be another
15 question. How many areas are we going to have in a given
16 container and what we may expect, either defects or
17 concentration composition--and so on. I don't know exactly
18 how that will be addressed by manufacturers.

19 Joe?

20 PAYER: Just one other followup on some of the issues
21 that Ralph mentioned. I think the concept of putting an
22 outer layer thin of C-22 or titanium on the outside of the
23 carbon steel in Zero is essentially sort of a natural
24 evolution or followon to the drip shield idea. It might be
25 the most effective and most reliable way of really putting a

1 drip shield on. The titanium or C-22 that would repassivate
2 would do that and to my mind would have a lot better chance
3 of staying in place and being fabricable and putting in there
4 than a separate monolithic ceramic shield that people are
5 talking about and those alloys both develop their own ceramic
6 coating in situ on their surface, and yet they have some
7 ductility. So, it's worthy, I think, of looking at it in
8 that perspective, as well.

9 STREICHER: I remember the carbon steel was that thick
10 because of radiolysis, also, right?

11 PAYER: Yes.

12 STREICHER: The original idea on carbon steel, that's
13 being replaced here by something better.

14 SAGÜÉS: Do we have any other comments?

15 (No response.)

16 SAGÜÉS: If not, I think that we're just about ready to
17 declare the morning session adjourned. Do we have any
18 announcements to make at this moment before the afternoon?

19 BULLEN: No, just back at 1:00 o'clock. That's it.

20 COPPERSMITH: We're going to try to reconvene and we
21 will reconvene at 1:00 o'clock sharp.

22 (Whereupon, a luncheon recess was taken.)

23

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AFTERNOON SESSION

4 COPPERSMITH: We are ready to convene the afternoon
5 session. We all have an unstated goal of early departure,
6 particularly those of us who had a very late departure
7 arriving.

8 Mike had asked for a couple of minutes to present a
9 semi-parking lot item. Maybe he's going to present it, and
10 then we'll put it in the parking lot, but he did want to say
11 a couple of words. I'm not sure, I think it's about the pour
12 canister for high level waste glass.

13 STREICHER: Yes, correct.

14 COPPERSMITH: Let me go through what we're going to do
15 for the remainder of the meeting here. We're going to finish
16 itemizing research needs, looking at the last alternative,
17 the number six alternative here. Then I'm going to go
18 through reading Carl Di Bella's handwriting, and I will
19 review those research needs that had been identified, try to
20 make sure that they seem to be reasonably complete and I
21 guess consistent with your understanding of what we
22 discussed.

23 Then we are not going to get into a rigorous sort
24 of prioritization type process here. We talked about it over
25 lunch, but I will maybe talk a little bit about what a next

1 step might be if we are going through a process of
2 prioritizing because it is important to deal with priorities.

3 Then we'll have--it's a wrap-up, and then everyone
4 is going to race to the airport. I will make an attempt at
5 the end to see if there are cases where drivers are willing
6 to take passengers and whatnot. We can optimize that system
7 to the airport.

8 But, Mike, are you ready?

9 STREICHER: Some compositions for these alloys that
10 we've been talking about; I will be talking about 304L. L
11 stands for extra low carbon, which means it's supposed to be
12 relatively immune to sensitization, which could lead to
13 intergranular attack.

14 And 316, a little less chromium, a little more
15 nickel, but 2 to 3 per cent molybdenum.

16 825 up here, somewhat higher chromium, a lot higher
17 nickel, but we have here, and that's what this alloy will
18 benefit from because higher nickel makes it resistant to
19 stress corrosion cracking--chloride stress corrosion
20 cracking. And as we've already said, it has copper in it,
21 which is beneficial to resist phosphoric and sulfuric acids,
22 but impairs pitting resistance.

23 C-22 has the higher chromium content, a much higher
24 nickel than this, makes it essentially immune to chloride
25 stress corrosion cracking. And it has a significant amount

1 of molybdenum, helps with pitting resistance and a few extra
2 elements here I won't go into.

3 276 is the predecessor to C-22, less chromium, and
4 that makes a big difference. It helps with resistance to
5 oxidizing acids. The corrosion resistance of 276 here is
6 lower in nitric acid than this alloy, significantly lower,
7 just because this has more chromium than the 276. That
8 little bit of chromium makes a big difference in oxidizing
9 environments.

10 I'll leave that up there for now.

11 I hope that is legible, but it doesn't really need
12 to be.

13 This is an order of resistance to seawater
14 corrosion. Beginning at the top, immunity, and down here,
15 progressively less resistant until we get to the bottom of
16 the barrel here, and it says there's attack outside the
17 crevices even. And 825 is at the bottom of the barrel here,
18 and it's not only from these particular tests in ocean water.

19 Incidentally, this test in ocean water can be
20 parallel by laboratory tests and ferric chloride, determining
21 the temperature at which a ferric chloride solution will
22 attack these different alloys. And there's a direct straight
23 line relationship between that temperature and ferric
24 chloride, which you can run in a lab at very little cost in a
25 big test tube and thermostatic bath, and it will parallel the

1 results here that were obtained at 62--well, 30 days of this
2 case, some of the tests run in association with this for
3 longer. At any rate, in a matter of a day or two, you can
4 determine in ferric chloride where a given new alloy let's
5 say would fall in this scale here.

6 Notice, 276 is right at the top of the list, and
7 this is merely an index for rating crevice corrosion, the
8 number of sites that corroded underneath the crevices and the
9 depth multiplied by each other.

10 PAYER: Mike, I can't see. Is C-22 on that list?

11 STREICHER: It is not. It wasn't developed then.

12 PAYER: But it would be up there, and you're predicting
13 it would be.

14 STREICHER: Oh, yes. Yes, it would be right at the top
15 there.

16 SHOESMITH: We hope it would be somewhere just above
17 where it says Table 1.

18 STREICHER: This is the kind of specimen that was used.
19 That's a teflon crevice; there's one on the back side. And
20 those tests were run in filtered seawater, the ones here.
21 The ones that I'm showing here, these two panels is actually
22 a different test. All it does is illustrate what goes on
23 here. This was not filtered seawater, and on this panel
24 there were all kinds of marine growths. It's all done at
25 Wrightsville Beach in North Carolina. And you can see that

1 there is almost as though they were machined out where the
2 attack took place underneath these teflon crevices, similarly
3 on the back, and this is attack underneath the marine
4 growths, 316L.

5 Here's Hastelloy C. C-22 would be similar, no
6 attack whatsoever. As I mentioned, these results parallel
7 the ferric chloride resistance.

8 Now, the story on chloride stress corrosion attack.
9 These are different alloys, but I'm only counting the nickel
10 content. Never mind the molybdenum or the chromium, only the
11 nickel content. And the test here, on this curve, was done
12 in magnesium chloride, which is the most severe chloride
13 stress corrosion test that we use in the laboratory, boiling
14 at 155 C, and you can see that without nickel, these iron
15 chromium materials are resistant, like here. However, as you
16 increase the nickel content, there's a precipitous drop, and
17 guess what? This is 304L right here. That's a logarithmic
18 scale. These are small U-Bend specimens, tightened up with a
19 bolt to make it look like a U. And this is 304L. It cracks
20 in that test in less than an hour.

21 As you increase the nickel content of these alloys,
22 and if you have 54 per cent nickel or so in C-22, you're in
23 the clear here; no cracking. And as I said, the other alloy
24 elements don't really have any major effect on this curve.

25 The test in sodium chloride here at 200 centigrades

1 in an autoclave, it gives you the same shape of curve, except
2 that it's narrower here, the U. Therefore, nickel content in
3 here will resist the sodium chloride test. So the sodium
4 chloride, which is more realistic when it comes to comparing
5 with the real world like in natural cooling waters, you can
6 get away with an alloy that has say 42 or 43 per cent nickel.
7 You don't need 55 or more.

8 STAHL: Mike, where would ferric chloride be on
9 that curve?

10 STREICHER: In stress corrosion? I have not done that,
11 so I really can't answer that. I've run lithium chloride and
12 so on, but not ever ferric chloride. Most of these alloys
13 would pit in boiling solution long before stress corrosion
14 would occur.

15 Now, the reason for bringing this up is that the
16 container of the glass waste, these are the logs being
17 produced at Savannah River right now, ten feet high, two feet
18 in diameter, being filled with molten glass. And that's
19 304L, the alloy there. And they're going to do this 6,000
20 times at Savannah River. There will be eventually 6,000.
21 That's the waste in the tanks, these million gallon tanks.

22 And after the conversion to glass, the surface
23 temperature here will take a long time to get down to 100 C,
24 and the logs eventually are supposed to go into Yucca
25 Mountain. In the meantime, they are going into concrete

1 lined silo-type holes in the ground.

2 The water table at Savannah River is at your feet,
3 and Savannah River plant is either within or right adjacent
4 to a Category 3 earthquake zone. That's the highest category
5 on the map that I was looking at.

6 Again, there will be 6,000 of these. Similar
7 plants are being built at Hanford, two plants, and eventually
8 there will be 14,000 logs.

9 And again, this is 304L, the alloy which is the
10 most susceptible of the austenitic stainless steels to
11 chloride stress corrosion.

12 And chloride stress corrosion, that's an example of
13 not a U-Bend specimen, but just a ground surface, which
14 induces stress in the surface. This was put in magnesium
15 chloride, and after 15 minutes of exposure, the cracks run
16 essentially perpendicular to the grinding marks. You don't
17 need a U-Bend specimen.

18 What is the minimum stress that will give you
19 chloride stress corrosion? What is the minimum temperature
20 at which chloride stress corrosion occurs? And what is the
21 minimum chloride concentration? The answer after some 50
22 years of high flow work on stress corrosion cracking is that
23 there is no minimum. And that's why in our chemical process
24 industry, the nastiest surprises in the materials field tend
25 to be stress corrosion failures, unexpected, you know, where

1 somebody thought, well, the temperature isn't very high here,
2 or the chloride concentration isn't very high. The problem,
3 of course, with chloride concentrations is that chlorides get
4 concentrated wherever you have a warm surface, so you're
5 never dealing with parts per million. You're dealing with
6 accumulations in most cases.

7 So there is no minimum amount of corrosion that you
8 need for stress corrosion cracking. You can have a stress
9 corrosion failure on a specimen that will only show evidence
10 of corrosion under a microscope at 300 magnification. Maybe
11 a little bit of attack on a slip line somewhere in the
12 microstructure. That's enough to initiate a chloride stress
13 corrosion crack.

14 And the chloride crack, one way to describe it is a
15 brutal failure in a ductal material. These alloys, they're
16 ductal. They have very good fabricability, but the failures
17 are brittle in the chloride stress corrosion. So they can
18 travel rather fast.

19 And I am concerned about this 304L material in
20 these containers, and the reason is that they will be in
21 these silos for how long? Nobody can really tell you. And
22 then they're supposed to maybe go to a temporary storage
23 site. Nobody knows where that is or what that will look
24 like. Eventually, they have to be transported to Yucca
25 Mountain, and no one knows, as far as I know, when that will

1 be, so that we have a situation here where there are an awful
2 lot of unknowns.

3 And a little chloride is enough to cause stress
4 corrosion cracking. These materials, these containers all
5 have residual potential stresses in them. Can't help it.
6 They're welded at the top automatically, so there will be
7 major stresses in these. You can't get rid of them, and you
8 can't get rid of chlorides. They're everywhere. You know,
9 every kind of natural water has chlorides in it.
10 Perspiration has chlorides. They're everywhere.

11 So, frankly, I'd like to change to C-22. Now, the
12 answer is we're going to put these logs, five of them, in a
13 bundle inside a C-22 container, and then carbon steel on the
14 outside. That's what the schematics look like now. But we
15 don't know how long it will be before these 304L containers
16 will be placed into the C-22 larger containment equipment.

17 If there's a stress corrosion failure and you
18 expose the glass in there to water, just plain water, you can
19 get something like this. This happens to be a graduate which
20 is being used just to hold this glass apparatus, which was
21 used in an autoclave test, and these are what we call glass
22 holders or cradles. That's a corrosion specimen. And so
23 there were two of these cradles. And this was a glass rod,
24 which we held inside the autoclave, and the autoclave was at
25 320 Centigrade, and this was run for three weeks. And that's

1 what happened to the glass. If you touch that, it crumbles.
2 That's the borosilicate laboratory glass, and what's in these
3 logs is also borosilicate glass. That was at 320 Centigrade
4 in deionized water.

5 We've run many stress corrosion tests for a hundred
6 days or more. That's 2,400 hours. And these borosilicate
7 flasks that we use for sodium chloride stress corrosion
8 tests, they will be etched after a thousand hours. So about
9 half the cross section of the glassware is gone, and if we
10 don't replace them, we run risk of cracking and having the
11 test spill out into the hood.

12 So over and over again, we have seen that glass,
13 borosilicate glass, is really not very resistant at 106
14 Centigrade, which is the boiling point of a saturated sodium
15 chloride solution.

16 So we have lots of evidence, if you want, that if
17 there were a breach of a 304L container and water got on it,
18 the glass wouldn't last very long at 100 or even more
19 Centigrade.

20 Just one more ferric chloride item. This is C-276
21 welded and then exposed in boiling 80 per cent acetic acid
22 with ferric chloride. And in three days of testing, the weld
23 metal--and this happens to be the zone here where the weld
24 joins the base plate--there are these rather deep pits in
25 ferric chloride. I didn't notice just now what the boiling

1 point or 80 per cent acetic acid is, but you can look at this
2 as a ferric chloride test with a pH that's lower than two,
3 which would be the normal pH if it were plain ferric
4 chloride.

5 Here was an acetic acid. That's relative benign
6 acid, particularly at 80 per cent. That would not attack
7 ordinary stainless steel, and it wouldn't attack C-276 at
8 all.

9 So this is ferric ion, a ferric chloride attack on
10 hastelloy type material, and here's another example of that.
11 So we've heard that weld bends have been tested, and they
12 need to be tested and looked at especially carefully.

13 Okay. That's my comments on that. So I'd like to
14 have the 304L problem put on that parking lot.

15 SAGÜÉS: I have a question. I have a question, Michael.

16 In your experience, what is the deepest pit that
17 you have seen in a corrosion resistant alloy type of plate?
18 I personally have seen things where 317L was penetrated
19 through a sheet one-quarter of an inch in thickness. Those
20 are the deepest pits I've ever seen in a stainless type of
21 alloy. And I was wondering, in your experience, what is the
22 deepest that you have seen?

23 STREICHER: I mean, that's a pretty good thickness. In
24 general, these materials are not used in that heavy a
25 section. I would say no more than that, but I'm not saying

1 it couldn't happen in much thicker material.

2 PAYER: But what we have observed, and I'm sure you've
3 seen it, too, Mike, is on the crevice corrosion test where
4 they're run vertical, and the plastic inserts strapped on it,
5 where that corrosion will penetrate from a crevice initiation
6 site down several centimeters or many inches, almost down to
7 the bottom of the specimen.

8 STREICHER: Yeah.

9 PAYER: So that's a crevice corrosion initiation.

10 STREICHER: Yeah, good point.

11 PAYER: And they're going down because the specific
12 gravity of the solution is higher, so it stays within the
13 crevice, and it gives these triangular sort of--there's a
14 picture of materials performance in one of those. So if you
15 get into a stable propagating crevice corrosion localized
16 corrosion process, it will go.

17 STREICHER: You mean this is where the plate--just
18 going--

19 PAYER: Yeah, like the specimens might show during the
20 pictures of, but if that's vertical, either in seawater or
21 wherever the test is, then the crevices are clamped onto the
22 sides. The bolt goes through here. The crevice corrosion
23 begins underneath there, but then staying within the metal
24 surface, it will grow several centimeters, inches down. But
25 the safe open pits initiate and grow along the vertical

1 surface, but not along the sides. Again, the rationale being
2 that up here it can trap the higher specific gravity. Here
3 it rolls off and it stables itself.

4 So, and the geometry of that is it starts in a very
5 sharp pit, but it Christmas trees out in these triangular.

6 STREICHER: And the pits are self-accelerating because
7 the environment in the pit becomes ever more acid and
8 accumulates chloride ions. The concentration of chlorides in
9 the pit goes up with time. And so in the flat surface, a pit
10 goes down and then forms a hollow, and then it penetrates the
11 surface around the initial penetration from below.

12 That paper that you have there, there's a picture
13 of that.

14 PARIZEK: When do they pacify? I thought they get so
15 deep and they pacify. When does that happen?

16 STREICHER: Once they get beyond a certain size, they've
17 had--

18 PARIZEK: Yeah, the width's too wide.

19 PAYER: Are you going to change the subject because I
20 wanted another follow-up with Mike. And maybe we can come
21 back to it in a minute, but what I'd like to take out of the
22 parking lot that Mike brought up was this issue of stress
23 corrosion cracking. And I agree with you, some of the
24 biggest sizes and really unknowns have been where stress
25 corrosion has reached up and grabbed us. And what guidance

1 do you give to the Yucca Mountain project to deal with stress
2 corrosion cracking? Maybe we can come back to that when Dick
3 is done, or whatever.

4 STREICHER: Well, stay away from 304L.

5 PAYER: Well, sure, obviously that. No question.

6 STREICHER: Use C-22.

7 PAYER: But based on the day that you show there, does
8 that give you enough confidence that we don't have to worry
9 about stress corrosion cracking in the Yucca Mountain
10 environment for C-22, or is there more research that's
11 necessary to show that?

12 STREICHER: My guess is that C-22 is going to be about
13 as good as you're going to be able to pay for. However, C-22
14 and C-276, Haynes has data that show that you can concoct
15 compositions in oil field type environments where even those
16 elements will fail by stress corrosion.

17 PAYER: So again, the approach would be to better
18 identify the environmental range in Yucca Mountain and see
19 that it doesn't overlap with any of those areas.

20 STREICHER: Yeah.

21 PAYER: The other thing, as Mike mentioned, was he
22 mentioned the correlation in going from seawater ranking
23 using boiling ferric chloride, but what the project has the
24 opportunity of doing is if they generate the boiling ferric
25 chloride data, they can then piggyback back to all that

1 seawater behavior for these alloys for longer term exposures
2 using that correlation in the other direction. You know,
3 we're trying to find some 10-year, 20-year analogs, and that
4 might be a bridge back and forth.

5 COPPERFIELD: Not to be outdone. Digby has a few
6 viewgraphs.

7 MACDONALD: I'd like to address two questions. First of
8 all, radiation has been given a bit of a bad name in this
9 discussion, so I would like to counter that. It has some
10 beneficial effects that we should be aware of.

11 Secondly, I'd like to answer the question, can you,
12 in fact, predict in a deterministic manner damage?

13 Okay. I'll do this hopefully very quickly.

14 I'll start with a story. The story involves a post
15 doc that I had, Steve Lenhart, when I went from Ohio State to
16 SRI in my second incarnation at SRI. Steve came with me, and
17 we had a project with DOE, basic energy sciences, to look at
18 statistics of pitting.

19 And one day he came into my office, and he says,
20 "I'm quitting." He says, "There's no rhyme nor reason to the
21 statistics of pitting. You're wrong." He says, "It's a
22 completely random event."

23 And what he had been doing was he had been counting
24 pits, and that, of course, is, you know, one of the more
25 exciting things to do in life. And he had a small electrical

1 chemical cell underneath the illuminated stage of a
2 microscope, and he was counting the number of pits.

3 And I said, you know, don't quit yet. You know, go
4 back and repeat these experiments.

5 He went back, and he came to my office a few weeks
6 later, and he says, "I found it, I found it." I said,
7 "What?" He says, "The number of pits I get depends upon the
8 setting on the power supply to the lamp in the microscope."
9 "Really?" He says, "Yes." He says, "I've gone back, and
10 I've repeated these experiments time and time again, and
11 first of all, this is what I see." This has been xeroxed a
12 few times. The image on the left here is at high intensity,
13 the high setting on the power supply. The image on the
14 right, and this is white light, is at a low intensity. This
15 is perfectly reproducible. And if you count pits, as Steve
16 did, and this is now 15-year old data, so that's why we had
17 the unit of lux.

18 SHOESMITH: Is he still counting?

19 MACDONALD: Does everyone know what a lux is?

20 SHOESMITH: Is he still counting?

21 MACDONALD: Sorry?

22 SHOESMITH: Is he still counting?

23 MACDONALD: No, he went on to a much higher paying job.

24 But this corresponds to somewhere around about a
25 milliwatt per centimeter squared of white light. And you can

1 see the number of pits that are produced is greatly
2 suppressed when you illuminate the specimen.

3 Well, we then had a contract through EPRI and
4 became very interested in this, and so we looked at a variety
5 of measures. Why they were interested in it is that power
6 stations, of course, are encapsulated in metals cans, I mean
7 the working fluid, and so there's no photons in there at all.
8 This is an important point; there are no photons in there at
9 all. And so they were interested in maybe we can put light
10 pipes through pressure boundaries and irradiate components
11 that tend to crack.

12 Now, let me tell you another story, too. The same
13 time that Steve Lenhart was doing this, we had a guy from
14 Israel, from the Damona Research Center, who worked on the
15 reactors there, and he got all excited because he claimed
16 that in the reactors that were subject to high gamma dose
17 rates, they never saw localized corrosion, but in components
18 outside of the high dose rate regions, they would see pitting
19 corrosion. So he got very excited about this.

20 Under the EPRI program, what we did was to really
21 look at the statistics, and we measured the distribution
22 functions for the breakdown voltage; that is, if I take 100
23 specimens and I measure the breakdown voltage, and I plop
24 that on probability paper, then I get a near normal
25 distribution. Both of these are near-normally distributed

1 systems, and you can see that illumination shifted the
2 breakdown voltage, the mean breakdown voltage, by 80 or so
3 millivolts in the positive direction. That doesn't seem like
4 very much, except the breakdown voltage, in the point defect
5 model at least, appears in an exponential, and it does mean a
6 big deal when it appears in an exponential.

7 Now, this was still in the sort of milliwatts per
8 centimeter squared power intensities, but one important fact
9 about the nature of the light is that the photon energy had
10 to be greater than the band gap of the oxide, and that
11 immediately provides a clue as to what's going on. It's
12 electron hole pair generation within the oxide expression of
13 the electric field. In other words, it's a photo dire
14 effect.

15 We did the same thing in measuring the induction
16 time. This is the illuminated case here. The induction time
17 is considerably increased over the non-illuminated case.

18 Finally--not finally, but as further evidence, we
19 have heard about metastable pitting; that is, you get the
20 spikes that occur, which are passivity breakdown events
21 followed by what I call prompt repassivation. It gives rise
22 to these spikes.

23 And finally, but not shown on this graph, but way
24 up here, is one of these events will result in a stable pit,
25 and the current will just increase continuously.

1 If you illuminate the system with 300 nanometer
2 light, which is a photon energy above the band gap, you know,
3 it's like giving whiskey to a baby. It quiets them down--not
4 that I do that.

5 PARIZEK: You would never have thought of--

6 MACDONALD: But you can see the remarkable effect the
7 radiation has on pitting corrosion.

8 But that's not the most impressive. This is the
9 most impressive. This is carbon steel or iron. Carbon steel
10 gives the same result. In this case we used 325 nanometer
11 light, which is a photon energy of 3.185 electron volts, a pH
12 of 8.3, .1 molar sodium chloride solution. And while we were
13 doing this work, Patrick Schmucki Bohni published a data
14 point of their own, and that's the one put here.

15 But you can see that when you get up to light
16 intensities of, you know, well, here even 400 milliwatts per
17 centimeter squared--and remember, you know, a common light
18 bulb is 60 watts, okay? So it gives you an idea of what
19 we're talking about in terms of power density, these systems
20 start to pit. I've put them up there as breakdown potential.
21 They don't break down. The current increases. That's due
22 to oxygen evolution, but they don't pit. They're stainless
23 iron.

24 Switch the light off and repeat the experiment, you
25 get the same result. Do it for 250 hours, the same result.

1 Then after 250 hours, you lose protection. You irradiate the
2 surface again, back comes the protection. It doesn't pit.

3 We've now tried this on various iron alloys; same
4 result. What happens is that when you irradiate the surface,
5 you generate electron hole pairs within the barrier layer.
6 Suppresses the electric field. You get a prompt effect
7 because you reduce the driving force for cation vacancies
8 going across the barrier layer with a condense of the metal
9 film interface, but you also modify the cation vacancy
10 profile, both cation and anion vacancy profiles across the
11 film.

12 If you take as a diffusivity for the vacancies of
13 10^{-19} centimeter squared per second, which is being measured
14 by impedance spectroscopy, and you simply use the expression
15 that D equals X squared divided by T , and you calculate what
16 T should be for reasonable thickness of the barrier layer,
17 you come up with a number of about 250 hours.

18 So what I'm arguing is that the delayed effect, the
19 persistent effect, is due to relaxation of the vacancy
20 structure within the barrier layer.

21 So that's what I wanted to say on radiation. You
22 know, there may be some beneficial effects of radiation, and
23 maybe we want to use a thinner canister. But, you know, with
24 gamma radiation, of course, while the energy of the photon is
25 high, the absorption and coefficient is very low. So you

1 get, you know, few absorption events, but nevertheless, you
2 know, when one does occur, everything rattles around at a
3 high rate.

4 So that's what I wanted to say about radiation,
5 that there are some demonstrated positive effects of
6 radiation on localized corrosion.

7 One way of thinking about it is this, and this gets
8 to your question, Mike. You've got gamma radiation coming
9 through this canister wall from this layer of water, and
10 you're producing radiolytic species, which in balance are
11 oxidizing, so you increase the corrosion potential, and
12 that's what people are being concerned about. It's the
13 increase in the corrosion potential. But by the same token,
14 you increase the breakdown potential. And so it may be that
15 the increase in breakdown potential more than offsets the
16 increase in the corrosion potential, in which case there
17 would be a net benefit of radiation. If that didn't occur,
18 then there would not be a net benefit.

19 The second thing is, can we realistically predict
20 corrosion damage deterministically. This is what we want to
21 calculate. This is a so-called damage function,, and what it
22 is, is the frequency of a number of localized corrosion
23 events per unit area versus the depth measured in increments,
24 and that's why it's expressed as a histogram.

25 There are several things that you need to note

1 about this, and this is an actual damage function published
2 by Ishikawa for 403 stainless steel, been buried in the
3 ground, and before they buried it, they actually measured the
4 damage function. They had some poor soul counting pits and
5 measuring the depths of pits. And they buried it in the
6 ground, and they dug it up after five years, and did another
7 damage function analysis.

8 Several things you have to note. First of all, the
9 integral under those is the total number of pits, and the
10 total number of pits went up.

11 The second thing is that the deepest pits are rare
12 events down here. There's a relatively few number of pits,
13 and this is what makes statistical analyses of pitting almost
14 impossible. It's like--you know, have you ever wondered, for
15 example, you have 400,000 people dying per year of lung
16 cancer because of smoking, why the insurance companies can't
17 go to somebody smoking and say, you're going to be dead in
18 five years, six months, ten days? They can't do that. And
19 they can't do that because the statistical models that they
20 use fail to capture the characteristics of the individual and
21 the impact that smoking has on the characteristics of that
22 individual. And secondly, the second reason is that dying
23 from cancer, lung cancer, as horrible as it may be, is still
24 a relatively rare event in the grand scheme of things.

25 And it's the same with pitting corrosion. The

1 things that cause failure, the pits that cause failure are
2 actually rare events. And that sort of phenomenon is very
3 poorly treated in a purely statistical manner.

4 The question is, can we calculate these things, and
5 what gives rise to this characteristic shape of the damage
6 function where we have a large population at small depths and
7 a small population at large depths. Is there something
8 important about that?

9 Just to show that Ishikawa's data, and this is for
10 Alloy 29-4C, again, you can see that in going from 310 hours
11 up to 598 hours, we have a large population of pits at
12 relatively small depths and a small population at relatively
13 large depths. But, of course, one pit, depending on the
14 system, is a failure.

15 Well, we did a study on this for the Gas Research
16 Institute. They were interested in seeing if we could
17 deterministically predict damage on condensing heat exchanges
18 because Congress had legislated thermodynamics. What
19 Congress said was that all heat exchanges, along with certain
20 output which essentially covered all of your home furnaces,
21 had to be 78 per cent efficient.

22 So I guess I was being a little unfair to Congress
23 to say that they legislated thermodynamics. What I should
24 have said is that their legislation forced the manufacturers
25 to make the heat exchanges so large that at the back end of

1 the heat exchanger, the temperature was below the dew point,
2 which is getting to the problem we have here, and they got
3 condensed on the surface a very thin layer of moisture. And
4 that moisture, by the way, reflected the lifestyle of the
5 people in the house.

6 Did you know that having a cat is dangerous to your
7 furnace? That's true. That's true. Having a cat is
8 dangerous to your furnace. And the reason why it's dangerous
9 to your furnace--and this is not my finding, this is from
10 Battelle. The reason why it's dangerous to your furnace is
11 that people have kitty litter for the cat, and the kitty
12 litter has a lot of chlorinated hydrocarbons in it. And the
13 chlorinated hydrocarbons get drawn into the furnace, burn to
14 the flame, and they get condensed out in the heat exchanger
15 downstream, and you end up with a concentrated chloride
16 solution. It's a big problem. It's a big problem for new
17 houses because they're now made to be more energy efficient.
18 We now take ambient air from inside the house and pass it
19 through our furnace in order to heat our homes, whereas in
20 older homes, they took air from the outside and passed it
21 through the furnace and then put it out back. So there's
22 some sociological problems in pitting corrosion.

23 Anyhow, this is very, very important. So we asked
24 to see if we could do a study, and I'll just run through this
25 very quickly.

1 Essentially what we had to do was to specify the
2 flu gas composition, the condensate temperature, the chloride
3 concentration duty cycle. In fact, that was all supplied to
4 us by GRI. And then we had models, deterministic models,
5 that calculated the corrosion potential using mixed potential
6 model, and the chemistry model, we calculated the pH of the
7 solution.

8 We have a pit nucleation model that is based upon
9 the point defect model, pit growth model, and a pit
10 repassivation model; why do pits repassivate. And you
11 combine all these things together in a fairly mathematical
12 nature, and you end up with a damage function model, which
13 gives you the damage function that I just showed you, and
14 this allows you to address questions such as the surface life
15 or thickness specifier and failure probability.

16 And to give you an idea of some of the parameters
17 that go into this calculation, I'm not going to go through
18 them all, I just want to point out that in principle, all of
19 these parameters, except this one here, can be measured by
20 independent experiment.

21 For example, the diffusivity of vacancies can be
22 measured by impedance spectroscopy. The critical vacancy
23 flux for metal such as nickel and stainless steel is roughly
24 equal to the passive current density divided by Faraday's
25 Constant just before breakdown.

1 The electric fuel strength can also be measured by
2 studying the thickness of the film as a function of voltage.

3 So most of these parameters, except this one here,
4 can be measured by independent means.

5 And when you go through all the mathematics, you
6 start to calculate damage functions. Now, if we look at the
7 first graph up here, we see that there's basically two
8 populations. There's a population at the highest depth,
9 which appears as one single spike. And by the way,
10 conditions were chosen for this calculation purposely so that
11 essentially the whole population of sites on the surface
12 nucleated pits at the shortest time. So we chose the
13 potential so that everything, boom, broke down at once, and
14 then we were looking at just the growth of pits and
15 repassivation.

16 If there was no repassivation of pits in this
17 system, then, in fact--and we've got new passivation given
18 here by this parameter--then, in fact, all we would have
19 observed, just a single straight line, vertical line. All
20 the pits would have grown in unison across the surface.

21 But because there's passivation, some pits die.
22 These are dead pits. These pits here died immediately after
23 they were born. These pits here died somewhat later. These
24 ones still later, and these pits here are still alive.
25 They're living pits.

1 If you go to a longer time, not only do the pits
2 grow to a greater depth, but more pits die. And now you can
3 see these pits here, these ones here, they're all dead pits;
4 dead as doorknobs, as they say. These pits are still alive.

5 Then when we go to still longer times, you can see
6 it is now starting to generate the shape that you see when
7 you actually measure damage functions. Virtually all of
8 these pits are dead, and there's just a few pits that are
9 alive. So now we come into our rare event scenario.

10 You can get the same thing, and this may, in fact--
11 no, sorry. Oh, I'm sorry.

12 If we look at it just for a given time, that is for
13 an observation time of one year, but now we change the
14 parameter that describes the root passivation of the pits.
15 If we make root passivation stronger, then we kill more pits,
16 of course. If we don't have any root passivation, the
17 scenario is that all pits nucleated in a very short time, and
18 they've all grown in unison, so we get one single straight
19 line.

20 As we increase the rate of repassivation, you can
21 see we start to form dead pits. And, in fact, all of these
22 pits are dead except for these ones here. In fact, I think
23 those are dead, too.

24 This comes back to the question, how deep does a
25 pit grow to. The conclusion from this is that the depth to

1 which pits will grow is totally dominated by whether the pits
2 remain--any pits remain alive. And, in fact, because you can
3 effect the rate of pit nucleation, I believe that this is an
4 effective means, by engineering the chemistry of the
5 environment, an effective means of limiting the depth to
6 which pits can penetrate and hence, limiting the amount of
7 damage.

8 So these pits here are essentially all dead because
9 you see, there's no further--well, it's a bit hard. Maybe
10 they're alive. Anyhow, if they're alive or dead, there is
11 very few of them.

12 Getting back to the heat exchanger problem. Here
13 are the experimental data measured by Stickford and
14 coworkers, et al., and what they did was to count pits and
15 measure the depths. And in this particular case, there's
16 some pits that at even at the shortest time had caused
17 failure, but at longer times--and these are separate
18 specimens. There's some pits here, not very many pits.
19 Here's some more, but now many pits have reached this
20 critical dimension. This dotted line is a critical
21 dimension. It's the thickness of the wall, and you see the
22 system has failed here and it's failed there.

23 But if you plot on it, when we simulated that--and
24 when we did this simulation, we had not taken into account
25 repassivation, and very few of the pits, however, were found

1 to repassivate on that system.

2 And what we did was to calculate the observation
3 time at which the extreme in this distribution intersected
4 this vertical line, which is about here. Now, you can see
5 that as we go to longer times, they're actually pitting air
6 because that's just a calculation out effect.

7 But the point is that we find the observation time
8 at which the upper extreme and the damage function exceeds
9 the critical dimension. And if we then compare--and this was
10 a completely blind study where GRI brought us and Battelle
11 together. I didn't see their results. They hadn't seen our
12 calculations, and we spent half a day in state college
13 plotting one point after the other. They would bring out a
14 point, we'd bring out a point type of thing. And Kevin Krist
15 was there looking at us.

16 And down here, their experiments didn't run long
17 enough to get failures. So these two are calculated points,
18 no failure, failure. Same here; no failure, failure.

19 Here they have asked us to leave this point out
20 because that was a--they said it was an experimental out
21 effect. I put it in anyhow. But they got a failure here, a
22 failure up here. We calculated no failure there and a
23 failure here in theory. So we were out by this, but
24 remember, this is a log scale.

25 The most reliable set of data are the high chloride

1 concentrations because this is the chloride concentration
2 that they could best control. And no failure, no failure.
3 There's a no failure theory under here somewhere, and then a
4 failure and a calculated failure.

5 So on the basis of that, I would argue that we can,
6 indeed, calculate deterministically failures. And we've done
7 this also for the neutrino experiment that's in Sudberry,
8 Ontario where they used--they needed a chlorine atom. They
9 used chloride instead of chlorate.

10 Finally, I just--

11 STREICHER: Is this still the heat exchange?

12 MACDONALD: That was the heat exchange.

13 STREICHER: Condenser?

14 MACDONALD: I'm sorry?

15 STREICHER: Condensate?

16 MACDONALD: Yeah, condensate, 304 stainless steel.

17 I just want to point out another thing, is that a--
18 I've mentioned this before. A deterministic model is a model
19 whose output is constrained by the natural laws. So all
20 models consist of constitutive equations and constraints.
21 Unfortunately, in corrosion science, people frequently leave
22 out the constraints, and then the models become a little more
23 than empirical correlations. But deterministic models have
24 the outputs being constrained by the natural laws.

25 In the case of localized corrosion, I'll show you

1 this one for stress corrosion cracking. That constraint is
2 the conservation of charge. It's an electric chemical
3 phenomenon, and what happens is that the current that exits
4 the mouth here, positive current, must be consumed on the
5 external surface, or a more general statement is that if you
6 integrated the net current density over this whole surface
7 like that, that net current density would have to be equal to
8 zero. It may be different in different places. In fact, you
9 find that there's a net positive current density down in the
10 crack and a net negative current density on the external
11 surfaces, but the integral over the whole lot must be equal
12 to zero, its conservation of charge.

13 And I'll just show you that one of the predictions
14 of this approach is that--and this is true for all localized
15 corrosion--is that the localized corrosion cavity cannot grow
16 faster than you can consume the current on the external
17 surface. You can't make it go faster than you can consume
18 the current.

19 And so we reasoned--this was some work we did for
20 EPRI as well, for Raj Pathania. We reasoned that if we put a
21 thin layer of zirconium oxide on the surface here, that we
22 could decrease the exchange current density for the oxygen
23 electrode reaction; that is, we would cut down the ability of
24 the reduction of oxygen on the external surface to consume
25 the current coming out of the crack, and the crack growth

1 rate should decrease.

2 We did this because in boiling water reactor
3 technology, they have this big problem of cracking of Type
4 304 stainless steel. Some people in the audience know full
5 well.

6 So we actually measured crack growth rates, 304
7 stainless steel. These are two specimens daisy-trained, and
8 we've done this several times where we have switched the
9 specimens around in the same autoclave, under the same
10 conditions, one coated with a thin layer of
11 electrophoretically deposited zirconium oxide, and the other
12 bare, okay, fracture mechanic specimens. And this is the
13 result. If you coat the specimen, this is crack length
14 versus time. If you coat the specimen, the crack growth
15 rate, which is the slope, is decreased.

16 Now, is it decreased by the right amount? I didn't
17 show you, but let me show you another--not only is the crack
18 growth rate decreased, but the corrosion potential is
19 decreased. This is, by the way, at 288 degrees centigrade,
20 so this is a little--well, maybe not different from what
21 we're talking about.

22 Here's the uncoated specimen, gives a corrosion
23 potential and a highly oxygenated solution of about plus 200
24 millivolts on the standard hydrogen scale. If you coat it,
25 you bring it down to about minus 200 millivolts.

1 We've also measured--sorry?

2 COPPERSMITH: Are you close to the end?

3 MACDONALD: Yeah, just the last one.

4 COPPERSMITH: Either that or another music story.

5 MACDONALD: We measured the resistance of the coating
6 using impedance spectroscopy, okay, on the barnacle scale
7 measured the resistance, and then we scaled the exchange
8 current density for oxygen reduction inversely with the
9 resistance, which essentially says that we have a certain
10 tumbling probability.

11 And what we found was that the zirconium oxide
12 increased the resistance of the interface by a factor of 100
13 to 1,000. Okay, so we would decrease the exchange current
14 density by .01 to .001. And what I plot here is the
15 calculated from the theory, corrosion potential versus
16 exchange current density relationship, and the crack growth
17 rate versus the exchange current density relationship.

18 And for the bare surface, remember, we were at 200
19 millivolts, were slightly out there. It should have been
20 down here somewhere. Crack growth rate, however, was pretty
21 close, reasonably close, and that down here we were--the
22 lowest crack growth rate we could measure is about 1 times
23 10^{-8} centimeters per second, so it's not bad, somewhere in
24 this region here.

25 So what I'm claiming is that by paying attention to

1 the need of the models, or any model, any deterministic
2 model, that their outputs be constrained by the natural laws,
3 that you can, in fact, make meaningful deterministic
4 calculation of corrosion.

5 COPPERSMITH: We're running out of time.

6 KESSLER: You're defining failure as first pit through.
7 Of course, the failure may need to be redefined for this
8 particular application. I can imagine first pit through
9 might allow gaseous radionuclides to escape, but they're
10 generally not considered terribly important in terms of
11 individual dose. What we need to worry about is when there's
12 enough pits through, that you can actually talk about enough
13 available surface area to get groundwater starting to flow
14 through. Is there anything that you've discussed that would
15 be an additional challenge to do that kind of a--

16 MACDONALD: That's no problem. For example, you could
17 define it as being some fraction of this curve. Instead of
18 being the first event through, you could be--you could define
19 it saying being 50 per cent of the events through the--

20 KESSLER: Are all these pit dimensions the same
21 diameter, so to speak? I mean--

22 MACDONALD: No.

23 KESSLER: Okay.

24 MACDONALD: No.

25 KESSLER: So the point is, what I need to know is the

1 surface area removed by pits is a function of time?

2 MACDONALD: Yeah, you could do that. I mean, at least
3 in principle. I haven't tried to do that, but you could do
4 that in principle.

5 COPPERSMITH: There would be a common link in growing
6 pit--

7 KESSLER: Yeah, right.

8 STREICHER: A very quick one. What did you do to solve
9 the problem?

10 MACDONALD: I'm sorry?

11 STREICHER: What did you do to solve the problem?

12 MACDONALD: Oh, you mean for the condensing heat
13 exchanges?

14 STREICHER: Yeah.

15 MACDONALD: That's a very interesting question. You
16 know, Battelle went through just about every alloy. I don't
17 think they did C-22, but they went through just about every
18 alloy you could think of, and they could not find a single
19 alloy that would meet the warranty requirements of the
20 manufacturers.

21 PAYER: They used 29-4C.

22 MACDONALD: Yeah, that was the best, I think, right,
23 29--

24 PAYER: Yeah, the superferritics were resistant to this
25 material.

1 MACDONALD: But they were looking at coated materials.

2 PAYER: Oh, yeah, they looked at a wide variety of
3 materials. None of the austenitics stainless steels could
4 hold up, but the superferritics did a great job. The problem
5 was that they then had to do all their tooling because they
6 don't form as readily. They broke their dies. So it was a
7 major issue. But the ferritic stainless steels do quite
8 nicely.

9 MACDONALD: But it wasn't only that. You know, the
10 profit for the manufacturer on a typical home heating unit is
11 very small. I mean, it's the order of, you know, 10 or 20
12 dollars, or something of that order. And, you know, to go to
13 these more expensive materials was a real burden on the
14 consumer, you and me I guess.

15 COPPERSMITH: We'll have to move on.

16 BULLEN: Sorry, I didn't mean to interrupt, but it's
17 described the Dan Bullen school of diplomacy, and I'd like to
18 interrupt speakers.

19 COPPERSMITH: You know we watch you when you do these
20 things, Dan.

21 BULLEN: You better believe it. I'm glad you're taking
22 notes.

23 COPPERSMITH: Okay, what we're going to do now quickly
24 is go back because I still have a goal of finishing before
25 3:30. Let's take a quick look at the harebrained--I mean,

1 Dan Bullen's Alternative Number 6.

2 One of the things that I heard in the course of the
3 discussion in terms of adding research needs, I think when we
4 dealt--right before lunch, we dealt with the issue of
5 repassivation, and we were talking about wall thickness. I
6 think some of these issues come up that deal with propagation
7 as related to wall thickness, how deep can pits go. And
8 again, to me, this all fits into the repassivation stifling
9 type of need.

10 Also, in terms of--Joe pointed out SCP. We need,
11 if nothing else, to better define the environments where
12 certain alloys might be susceptible to stress corrosion
13 cracking. And I don't know if others came out during the
14 course of the discussion.

15 Okay. If we deal with either this--I guess go over
16 some of the important things on Item Number 6, or things we
17 wrote down at the bottom, just generally the concept of a
18 smaller canister, and potentially a backfill, tuff backfill
19 type of scenario and shielding. And we got into some
20 discussion about all of these earlier today, but have not
21 talked too much about the research needs that would be
22 associated with those types of concepts.

23 We did hear--I think Tom mentioned some of the
24 issues related to fabricability for--and additional welds and
25 so on for a smaller canister.

1 Are there other issues that the research needs that
2 should be--you might think about when it comes to a smaller
3 canister?

4 PARIZEK: The vertical borehole, you could visualize
5 having water ponded and controlled by fractures, so you might
6 actually have a canister sitting in water when it cooled off.
7 I think it happened in this case, submerges portions of your
8 waste package.

9 BULLEN: When we looked at borehole emplacement in the
10 early part of the SCP, that was one of the failure
11 mechanisms, was if you had a hot borehole, you could actually
12 alter the near-field geochemistry and stop the water from
13 flowing and make it a bathtub and fill it up. I don't know--
14 I mean, that's sort of near-field, not in-package kind of
15 issues, but those kinds of things, as opposed to, you know,
16 for vertical emplacement.

17 And in addition, I guess none of the materials
18 issues associated with any of the things that we talked
19 about, whether it be shielding, ventilation rock,
20 consolidation, smaller canisters are any different as long as
21 we've got the same materials that we're using.

22 And so for Number 6, whether or not you go to
23 Number 4, which is a cast steel, or if you're going to go up
24 to a Number 2 prime, which is a titanium, and/or C-22 over
25 some other structural material, that materials research

1 issues probably don't--

2 COPPERSMITH: Those are the same.

3 BULLEN: Yeah, don't change at all.

4 COPPERSMITH: Okay.

5 BULLEN: I guess the only other thing that you deal with
6 is that we did talk about phase stability issues and the--

7 COPPERSMITH: Long time, we're dealing with the whole
8 passive corrosion process.

9 BULLEN: Right, and, also, you know, when you deal with
10 a material like C-22 phase stability, in the welded or base
11 metal condition, and how big are those inter-metallics that
12 you form relative to the passive layer as it propagates
13 through the material. I mean, if I've got a passive layer
14 that's on the order of a nanometer thick and I hit something
15 that's a micron--or micron inside, that's, you know, three
16 orders of magnitude larger. So I could jump ahead if that
17 thing falls out. I mean, if I have a small inter-metallic
18 that's got to be--I have a different corrosion potential or a
19 different electrical chemical characteristics in the near-
20 field, basically I could essentially propagate that funnel a
21 lot faster. I could sweep those defects along, as Alberto
22 mentioned this morning.

23 So those kinds of issues, unless, of course, you
24 want to post-weld heat treat, which is always my favorite.

25 COPPERSMITH: I think we've sensed that.

1 BULLEN: Yes. But I don't see any new research areas
2 that aren't already addressed.

3 COPPERSMITH: And we've talked about in terms of a
4 backfill, dealing with the tuff metal interface, in terms of
5 the development, potential development of crevices in that
6 area. Shielding, let's assume that shielding is a desirable
7 thing and is something that, in fact, would be of benefit.
8 Are there areas there that should be looked into in terms of
9 additional research or not? Is it pretty clear?

10 BULLEN: That's a pretty straightforward thing to do.
11 It's not really a problem. I guess the issue with tuff
12 backfilling has to do with the fact that how hot are you
13 going to let the containers get? How hot are you going to
14 allow the internal oven to get.

15 COPPERSMITH: Internal.

16 BULLEN: And so that's the issue, is when are you going
17 to do it? What kind of credit are you going to take. If you
18 want to take clad credit, then you can't backfill with a high
19 power container early on because you just exceeded 350
20 degrees C limit.

21 COPPERSMITH: Presumably, there's size and weight issues
22 here.

23 BULLEN: Yes, exactly. So you're going to change
24 container design parameters with respect to backfilling.

25 COPPERSMITH: They all change.

1 BULLEN: Right, but I think that's pretty well known. I
2 mean, you can do those calculations, and there's not really
3 any additional research necessary in the backfill case. It's
4 just a programmatic decision as to whether or not you want to
5 make them hot sooner or later.

6 COPPERSMITH: Is it worthwhile to look at temperatures,
7 you know, 400 degrees, 450, things like that, to look at--
8 other than cladding, other effects?

9 BULLEN: Well, you don't want to make these things hot
10 forever. I mean, it was in 304L, we looked at long-term, low
11 temperature sensitization. A guy named Michael Fox a long
12 time ago looked at the kind of formation of the M-23, C-6
13 carbides at the grain boundary and the like. And so you've
14 got sensitized microstructure for a 250 degree or 300 degree
15 anneal for a thousand years.

16 If you go to 400 or 500 degrees, I'm not exactly
17 sure how long you're going to stay there, you know, but
18 potentially if you stay there for eight or ten thousand
19 years, that would cast a little bit of a doubt on, you know,
20 long term thermodynamics stability of these materials.
21 Obviously, we don't have any natural analogs for C-22 sitting
22 around on the order of centuries at high temperature. And so
23 you look at the types of inter-metallics that might form, any
24 other secondary phases that may be projected from
25 thermodynamic calculations that you may never see in a

1 laboratory, but, you know, in 10,000 years they might show
2 up. So those kinds of issues.

3 STREICHER: Excuse me. You're aware of the test at
4 Haynes?

5 BULLEN: Haynes has got 50,000 an hour anneals, I know.
6 That's exactly right, and they have good data. And so the
7 issues that you raise there basically are you don't want to
8 go too hot. I mean, I wouldn't want to see these things
9 sitting at 500 degrees C for a thousand years, but I also
10 don't think that there's anything magic about 350 degrees C
11 for an hour that, you know, might buy you a lot with respect
12 to how do I know the base metal is going to perform now.

13 PAYER: I would support Dan's comments of not wanting to
14 go much hotter for long periods of time, primarily, if
15 nothing else, just on the analyzeability issue, trying to
16 determine what's happening during the hot period and the dry-
17 out and the re-wetting, and extending that to higher
18 temperatures, longer times makes it even more uncertain.

19 And it also--it's difficult enough to put to rest
20 these issues of long-term metallurgical stability of the
21 alloys, and those are all time temperature phenomena. So if
22 you jack up the temperature, you just open up more longer
23 uncertain times. So 350 is probably, you know, a reasonable
24 place to stop. And I don't know of any real technological
25 benefits from going higher than that.

1 BULLEN: The only technological benefit I see to
2 exceeding this 350 limit has to do with the fact that you
3 will have to compromise cladding if you want to post-weld
4 heat treat, and that's on the order of hours. I mean, you
5 know, I say an hour at 1000 or 1100 degrees C, but you've got
6 to heat it up and cool it down, so it's like a day at the
7 most kind of issue.

8 COPPERSMITH: The last thing that's on here that we
9 hadn't talked about was ventilation. And I know there's work
10 going on looking at alternative ventilation ideas. Is this
11 an area that we should recommend be pursued to look at
12 ventilation sufficiency?

13 BULLEN: This is a parking lot issue in some cases
14 because ventilation in the near-field has a lot to do with
15 tunnel stability. It has a lot to do with accessibility. It
16 has a lot to do with other issues aside from waste package
17 performance. But ventilation, in and of itself, has some
18 benefits with respect to package performance because of the
19 fact that we can limit surface temperature of the package.
20 We can also limit wall temperatures. We can have
21 accessibility. We can worry about--in the case of
22 ventilation, if we don't heat the mountain up as much, we may
23 not mobilize as much water, which means we may not have water
24 raining on packages or water moving around. But that's
25 beyond the scope of waste package performance. Great idea in

1 the parking lot, and I think it's an issue that the Board is
2 interested in.

3 KESSLER: Well, I thought that Joe Payer had also
4 suggested that it may be a negative if you can't keep the
5 humidity low at the same time.

6 PAYER: I think the point I made is I included in the
7 time that you could be in a vulnerable region, that if, in
8 fact, the humidity did get up, I have no reason to believe
9 that would happen, but then you would get into the cool
10 period.

11 I think the comment I would make on ventilation,
12 however, is that if it has the benefits, but I think it would
13 be a mistake to have the necessity of effective ventilation
14 on all packages in order to meet the performance because
15 there's a lot of things that could interrupt it in my mind.

16 So it's a nice thing to have and it makes benefit
17 and it helps the monitoring-type things and it comes along,
18 but I don't think it's something you want to bet the farm on.

19 BULLEN: I'm not talking ventilation just for waste
20 package performance. I'm looking at overall repository
21 performance, which is beyond the scope of what we are trying
22 to address here.

23 I do like the idea of a very limited perturbation
24 in the mountain, but that's beyond the scope of what we need
25 to do here, also.

1 COPPERSMITH: Okay. Before we forget, we're, you know,
2 dealing with many of these things that relate to design, but
3 I think John Kessler brought up some of the aspects that
4 relate to performance assessment. One of the things that is
5 very important is the distribution in time of failures or
6 penetrations. How is that modeled? Is there a research that
7 can be done that give a better--you asked the question about
8 how do we model, let's say, for example, the pit propagation,
9 the actual life cycle of pits, you know, the metastable pits
10 and their depth, and, you know, repassivation and develop new
11 pits and so on, and the development of those types of damage
12 functions that's a function of really the wall thickness.
13 How does that work its way into a performance assessment?

14 One of the things that ultimately I think you need
15 is at the time that you make it through wall thickness is the
16 rate, the number, the pit density of growing pits, but you
17 don't stop there because failure is defined as complete
18 failure and complete release, so that the process in the
19 performance assessment, unlike a highly pressurized pipe that
20 when it breaks in one place, you're done, that the full
21 propagation and the geometry of the failure is very important
22 over long time periods.

23 And so any advice or research in that area?

24 MACDONALD: The most difficult thing is to be able to
25 describe future events.

1 COPPERSMITH: Absolutely.

2 MACDONALD: You're going to have a crystal ball there,
3 okay, because you can make any model--well, you can't make
4 any model, but as much as you can make a model deterministic,
5 the ultimate weakness in the whole shebang is your ability to
6 be able to perceive the future, to describe the future.

7 So, you know, you have to look in your crystal ball
8 and say, you know, the temperatures get--just like these graphs
9 that you had up with regards to temperature. If you could
10 describe those in a principle, there's no reason why you
11 can't model them.

12 KESSLER: But the way they're being done now is they're
13 being split up into a set of discreet scenarios of how the
14 future site evolves, and the undisturbed scenario is such
15 that there may be uncertainty as to how much water is going
16 down through the mountain. But we don't need to worry about
17 particularly seismic events in the undisturbed scenario. I
18 mean, in other cases you have to worry about seismic events
19 and when they occur, and then there's volcanism and things
20 like that. If you look at a base case scenario, maybe
21 there's some of those issues we can take off the table, just
22 the way it's stylistically done.

23 PAYER: If the materials behave the way we talked about
24 here, and the C-22 and the titanium are the material choice,
25 and laboratory demonstrations are--it's not a pitting

1 mechanism. We're not talking about trying to predict a
2 population of pits that grow to, you know, through the wall.
3 It's more of a general corrosion, uniform corrosion that's
4 occurring in areas, but they're not pit areas. They're over
5 several centimeters or several tens of centimeters, hundreds
6 of centimeters.

7 KESSLER: Or 310 squared centimeters, yes.

8 PAYER: Well, yeah, that's a model again, you know. And
9 so that damage is going to have to be determined by how large
10 a patch, and that's going to be driven I think much more by
11 the distribution of moisture and where the damage occurs
12 turning it on and off, and then you plug in the general
13 corrosion rate that we have for passive metals. That's the
14 concept that would logically follow from the kind of
15 materials we're talking about. If we get into stable pit
16 propagation, then we've missed something.

17 COPPERSMITH: Let's go back. Remember the results that
18 were shown, the results from TSPA--

19 PAYER: That's a pitting model.

20 COPPERSMITH: No, no, what you saw is that those--the
21 dominant--those things that would lead to the dominant
22 release were out there in the hundreds of thousands of years,
23 those were all general corrosion. That is all passive
24 dissolution that now dominates for the present design with
25 the C-22.

1 PAYER: And I think that approach needs some refinement,
2 and it needs some rethinking in terms of where is it going to
3 be wet and how are you going to distribute it. But that is,
4 in fact, the type of mode we're talking about, not the growth
5 of pit penetrations.

6 COPPERSMITH: Right. I mean, this is what we're looking
7 at over these time periods.

8 So let's say that we're a John Kessler or a Bob
9 Andrews or anyone else who is out of their mind enough to
10 want to do performance assessment.

11 KESSLER: That's why they put me in this corner.

12 COPPERSMITH: And I do a lot of performance assessments
13 for other sites. The problem is, and it gets back to what
14 John was asking you yesterday, is how much of this problem--
15 let's say that we are developing an estimate of the passive
16 dissolution rate of C-22, and someone asks you that, what is
17 it. And if you say, well, I think--well, my best estimate is
18 it's a micron per year, but it might be as low as .1, it
19 might be as high as 8, okay? And that's an estimate that has
20 an uncertainty associated with it.

21 When it goes into performance assessment, that
22 uncertainty is propagated through and is usually taken as
23 spatial variability on different patches, on different
24 canisters, at different locations. And so now you have a
25 patch over here that has .1, here's one that's .3, here's

1 another one over here that's .5, and so on. And then that,
2 it basically gets propagated.

3 And I guess the question that was asked yesterday,
4 and I want to be sure that everyone agrees with their answer
5 from yesterday, is John asked you to consider a situation
6 where we know there's a lot of spatial variability in the
7 environmental case of where drips are, how frequently they
8 happen, what chemistries there are, and so on. But assuming
9 the environment is perfectly the same and we now are dealing
10 entirely with the uncertainty or variability that would come
11 from your estimate of corrosion laws and uncertainties in
12 just that example, let's say in the passive dissolution rate
13 for C-22, how much uncertainty do you think that will
14 contribute? How much of this characterization of variability
15 comes from this part of the problem, the corrosion part of
16 the problem?

17 SHOESMITH: First of all, I caution against assuming
18 that a passive corrosion process is a simple linear growth
19 law. It is conservative--we assume it is conservative to
20 take it to be that. Film growth laws would have roughly the
21 same shape as pit growth laws, except we can see that they,
22 you know, will reach some barrier thickness which doesn't
23 vary, and then it will go linear.

24 We heard enough scenario, such as the possibility
25 of accelerating when you hit a defect. There is a

1 possibility, of course, a defect is cathodic and you actually
2 decelerate, but that's another point. There's enough
3 evidence out that say that we would not expect passive
4 corrosion necessary to be a simple linear process, which
5 means every site fails.

6 So, for instance, if you did have a norm
7 distribution of defects, and if you could say that the
8 various distributions of defects will accelerate and
9 decelerate, you will get a very wide distribution and local
10 penetration points even for passive corrosion.

11 So I don't think we can dismiss the growth law, the
12 need to have a growth law model of passive corrosion. And
13 you will get some variability out of it. The thing is, right
14 now, we can't specify what it will be.

15 COPPERSMITH: Merely because of the lack of experimental
16 evidence?

17 SHOESMITH: Yeah, exactly.

18 KESSLER: And the point is, can this panel make some
19 recommendations on how to get a handle on that.

20 COPPERSMITH: Which would recommend how that could be
21 tackled.

22 SHOESMITH: I think we're dealing with something which
23 most people have not dealt with experimentally or in modeling
24 terms, with the exception, perhaps, of what Digby has done on
25 passive films.

1 MACDONALD: Let me ask a question. How were these
2 curves derived? I mean, what's, you know, the technical
3 basis for them? What models did--

4 PAYER: Did you have the viewgraph?

5 COPPERSMITH: Given the time--

6 PAYER: Well, I mean, did you have the viewgraph,
7 though, of the--WAPDEG and all that? You could at least show
8 them the boxes that are relative to--somebody showed that.

9 COPPERSMITH: Yeah, I showed that.

10 MACDONALD: Possibly--you know, penetration by the first
11 pit after 10^5 years.

12 COPPERSMITH: Yeah, but see, this takes into account not
13 just the first pit, and the concept is that it carries
14 through the entire--the sort of logic diagram where you have
15 drips, you have the elevated pH, you have different
16 concentrated solutions and so on. And when you put them
17 together, you basically find that the passive dissolution
18 rate of C-22 is a very deciding feature. That's very
19 important, and so is the localized corrosion rate because
20 there is a potential of the development of more aggressive
21 conditions locally, and that can occur.

22 And so these are areas that have been shown by
23 sensitivity analysis to be very important to at least the
24 base case design, I think potentially for a lot of these
25 designs, is the nature of these growth laws.

1 We've already talked about the initiation
2 repassivation being very important.

3 MACDONALD: Are these deterministic models? Are they
4 just wishful thinking or--

5 COPPERSMITH: I don't want to get into it because your
6 definition of deterministic is different from mine. But I
7 think if John Scully was here, he would say, yes, they're all
8 based on basic electrochemical theory. That's what
9 determinism is. They're probabilistic from the standpoint
10 they incorporate uncertainty.

11 So these--right now, I guess a PA modeler right now
12 wants to know, or ultimately for licensing or for
13 confirmation, would want to know how much of the knowledge
14 that goes into let's say a passive dissolution law or some
15 other aspect is likely to be irreducible in the future, is
16 purely variability, should be modeled as just variability
17 across the population of waste packages, and how much of it,
18 in fact, is uncertainty related to our lack of knowledge
19 about the shape and other features of, for example, a growth
20 law?

21 That's a constant question. We asked it of the
22 waste package degradation expert elicitation and we got: tell
23 me again the difference between variability and uncertainty.
24 It's a very difficult problem, but it ends up being one that
25 is very important to the performance assessment. And other

1 than maybe put it in a research need for PA analysts, this
2 will come up time and time again of how do we deal with some
3 of these issues like the long-term distribution of failures
4 of these waste packages. That's a very important component.

5 PAYER: I would suggest that it's an important thing
6 that has to be dealt with. The approach to it would be to
7 get a PA person or persons with the corrosion person or
8 persons, like Dave Shoesmith and Mike, some of the project
9 people, and hammer that out. And it's going to have--any
10 general corrosion measurements we make, you expose 10 as
11 identical specimens as you can, and you get a range of weight
12 losses.

13 We're going to see that in this phenomena also, and
14 there's other reasons. And so it's not going to be a single
15 value. We know there is going to be some scatter in that,
16 and I think, you know, the approach could be to take those
17 instances where we have this data for this type of breakdown
18 process, and we don't--well, Dave said we don't exactly have
19 that, but we've got some. And then just say, okay, we're
20 going to apply this because we don't know any more about
21 that.

22 And the other thing is, we're pushing those out to
23 such low corrosion rates that, you know, I mean, it's not
24 going to be measurable. So it's going to have to be
25 something you deal with analytically. The good news is that

1 you're--you know, if this works, you're pushing the failures
2 of the packages out to the ten thousand year time frame and
3 that. So it shouldn't have a major effect on the early
4 predictions or measurements, and then you get this big burst
5 whenever--

6 COPPERSMITH: But you can see, your example is a great
7 one of 10 identical specimens in an identical solution and
8 still getting a scatter. Okay, and now picture 10,000 waste
9 packages and put them in identical solutions, identical
10 environments. You would assume that there would be some
11 distribution as well.

12 And that's very important to the idea of a peak
13 dose or the idea of a sudden failure or common cause type
14 failure mode. Everyone agrees that the environment is highly
15 spatial and heterogeneous, and hopefully there will be some
16 clear exposition of what that is that's being worked on.

17 But the degree to which this variability or the
18 dose is spread out over time and over space could largely be
19 a function of the waste package behavior, too. Right now we
20 don't know what component that is.

21 Did you want to say it another way, John?

22 KESSLER: No, no. I was going to--

23 COPPERSMITH: The PA analyst is always in a state of
24 anxiety about this issue because it ends up being important.

25 Yeah, Mike?

1 STREICHER: When you say passive corrosion rate, in
2 what? What environment were you thinking of?

3 COPPERSMITH: Well, I think a given environment I think
4 would be the case here. It's just for a given environment.

5 STREICHER: For a given environment that you've assumed
6 --you're going to synthesize what environment you expect to
7 see--

8 COPPERSMITH: Right, at some point in time and space.

9 STREICHER: Okay. And then establish a passive
10 corrosion rate for that environment--

11 COPPERSMITH: Right.

12 STREICHER: --is what you'd like to do, without pits or
13 anything else?

14 COPPERSMITH: Right.

15 SHOESMITH: Yeah, the data that went into that line,
16 this is not a satisfactory situation, but it's an example of
17 how eventually PA takes leave of reality by necessity. The
18 values that went into the passive corrosion range over five
19 orders of magnitude, the values at the top end were recorded
20 in things like 10 per cent sulfuric acid, 10 per cent ferric
21 chloride. They are up to two orders of magnitude more than
22 the values measured in saline brines in Germany.

23 So the distribution includes some very wild values
24 at the top end for the environments that we think might be
25 possible in this mountain, which is effectively saying that

1 you have adopted conservative limits to cover up for the fact
2 that you can't predict.

3 Now, this is not a satisfactory situation. It will
4 be much better for new growth laws and variabilities and all
5 that kind of stuff, but encapsulated in there is the
6 uncertainty, and covering the uncertainty are the assumption
7 that there is some really weird high values in there; like I
8 think there is a passive corrosion rate which is well over 20
9 microns a year, will be the top end of that distribution of
10 values. Now, that's unrealistic, but given how little we
11 know for this environment, it's a good idea to keep it in
12 there for the moment.

13 STREICHER: You can have a passive corrosion rate on
14 Hastelloy C or 276 in boiling 50 per cent sulfuric acid.

15 SHOESMITH: Excuse me, I didn't mean to say it was
16 unrealistic of the conditions under which it is measured. I
17 meant to say that those conditions are unrealistic compared
18 to what you can get in the mountain. No, I'm not disputing
19 the value. I'm just saying that the values are incorporated
20 in the analysis, which are unachievable under Yucca Mountain
21 conditions, not that they're wrong from the measurements. I
22 believe they are right. They're probably the most accurate
23 numbers in there.

24 PAYER: The answer is no?

25 SHOESMITH: What was the question?

1 PAYER: Can this be done easily?

2 SHOESMITH: Yeah, it sounds like this is a very
3 difficult--

4 PAYER: I think it's going to have to be handled by
5 analysis and analogy, not by running dip and dunk
6 experiments, or maybe there are some electrochemical
7 experiments that can shed some light on it, passive current
8 densities perhaps, that you could--but that's where it's at.

9 MACDONALD: I saw the Japanese take--in this whole
10 scenario--this whole business years ago was that they tried
11 to calculate what the geological conditions would be, you
12 know, 100,000, 10,000 years and so forth into the future.
13 And then they set up experiments that would simulate those
14 particular conditions.

15 And I think in certain cases that approach is
16 valuable. But, of course, one of the issues with corrosion
17 science is that it has a memory, and the whole corroding
18 systems have a memory. So somehow you have to capture that
19 memory.

20 KESSLER: The entire history up until that point, yeah.

21 MACDONALD: But nevertheless, it sort of goes a little
22 bit along the road.

23 KESSLER: I was going to ask another question about
24 natural analogs. I recognize that the ancient Romans didn't
25 build their chariot wheels out of C-22, but is there

1 something in terms of ancient materials that can be used
2 successfully and at least reining in these huge uncertainty
3 bounds that Dave was just mentioning a few minutes ago for
4 analogous materials?

5 STREICHER: For one material, titanium, you can't do
6 that, all right, and you can't do it for--except for
7 meteorites, for nickel material.

8 SHOESMITH: There are other ways to give yourself a
9 little degree of certainty, though. So, for instance, for
10 titanium, I think the amount of steam-generated tubing out
11 there is enough to go around the world about 10 times. The
12 number of crevice corrosion failures have always been on the
13 gasket materials. They've been thinning down the wall
14 material for the last 20 years as they supply it because they
15 are seeing an aerated chloride solution under a heat source
16 condition, no corrosion.

17 So and that's 20 to 40-year data. So what you've
18 done is compensated for lack of time by effectively having a
19 much larger surface area of experience.

20 So although the time factor is not there, there are
21 reassurance from common usage. Now, this is not enough
22 necessarily, but I mean, those kind of things are there for
23 some of these materials.

24 COPPERSMITH: Okay. I'm going to start--I think Carl
25 has a running list of research needs, and I'm going to go

1 back to his Page 1 and go through those. I think it's
2 important that we've captured these ideas. It's also
3 important that I be able to read his writing.

4 DI BELLA: I'll stand by to help you read it, if
5 necessary.

6 COPPERSMITH: Feel free to delete any or add to or
7 revise any as we go through this process.

8 Okay. So let me go through research needs. There
9 are editorial comments here by Carl on--that I won't
10 necessarily read to you that has to deal with the overall
11 credibility of the person proposing the--okay.

12 So go back, if you can remember, earlier today we
13 talked about the issue of defining monitoring needs, a long-
14 term performance confirmation, saying what is needed in terms
15 of monitoring? What do we need to do? How important is it
16 that we be--just the ability to monitor the condition over
17 long-time periods? It isn't clear that that's important.
18 That's something that needs to be looked into.

19 Determine the pros and cons of ventilation. We put
20 it in the parking lot, but it's, I think, easy enough to look
21 at some of the pros and cons and values of ventilation.

22 And then we began to look at Option 0, which is the
23 carbon steel over C-22. It was said that an important
24 research need is to look at actual dripping water,
25 groundwater presumably, site specific groundwater on the

1 heated surfaces, particularly on the carbon steel, and to
2 look at the changes in concentration that would occur. The
3 chemical constituents that come out of that type of test can
4 be very important in basically looking at the ionic soup that
5 would come from that and its corrosion potential.

6 The issue for carbon steel, rapid corrosion
7 followed by spalling. Again, sort of the issue of the
8 behavior of carbon steel, a potential research need.

9 Let's see, water chemistry due to the interaction
10 with carbon steel. So this would be, I guess in one case
11 it's heat, and here's a case where it's also the interaction
12 with carbon steel. So many of the designs that deal with
13 water coming down onto the titanium or the C-22 in accordance
14 are going to be dealing with the heat issue. Here's real
15 tests and potentially code calculations that would look at
16 that interaction with carbon steel.

17 Dan McCright is sitting there saying, why are they
18 doing all this stuff.

19 Then we get to a discussion. Joe Payer had some
20 great research needs that related to the temperature of the
21 onset of localized corrosion. I think--and then talked about
22 that as a function of pH, Eh and a number of other conditions
23 for C-22. Various titanium alloys, we weren't too specific
24 on which alloys of titanium to look at, but there was some
25 discussion there. Maintaining, keeping 825, if nothing else,

1 was a basis of comparison downstream, and this is potentially
2 both electrochemical and corrosion experiments. It was said
3 that these are not necessarily super long-term. They could
4 be done in a reasonable period of time, as I recall.

5 Then looking at the TAQ, the aqueous temperature,
6 as it may be largely a function of solution chemistries. So
7 we're coming at this from, as I view it, defining the window
8 susceptibility on the upper side and on the lower side. I
9 think Gustavo also dealt with some of these issues of
10 defining those boundaries, if you will, to the windows of
11 susceptibility.

12 And then I guess, as you call these, the extreme
13 boundaries, if you have a sort of four or five dimensional
14 window susceptibility that's got pH, Eh, chloride content,
15 nitrate, sulfate, all of those things that are in this mix,
16 how do they work together in terms with the development of
17 aggressive solutions.

18 And let's see, I guess that could be your comment,
19 is this needs experimental work, not just models.

20 Okay. The growth or stifling of crevices, that's a
21 critical need for C-22. The question is whether or not it's
22 also a critical need for titanium. But I think we've dealt
23 with that. I think, to me, this is, no matter how we deal
24 with it, the issue of initiation, propagation stifling.
25 Either you come at it from attempting to initiate and see how

1 quickly things repassivate or deal with it coming from the
2 other direction. It sounds like this is a very important
3 item either way.

4 Last, the discussion had to deal with the passive
5 corrosion process and better describing the nature of that
6 growth.

7 Let's see, demonstrating no unknown events in
8 10^6 years. Does this gets into phase stability and other
9 types of issues? I don't remember that one. Do you
10 remember?

11 DI BELLA: Joe, did that come from you, do you remember?
12 I know there was no discussion of that particular--

13 COPPERSMITH: Demonstrate no untorrid events in 10^6
14 years. I think it was dealing with long-time--and whether or
15 not you might have defects and phase changes. I was going to
16 ask you how do you do that.

17 PAYER: I think it was when Alberto was talking about as
18 this passive film grows very slowly through there, does it--
19 with that uncertainty of these, if it is, in fact, corroding
20 in a passive manner.

21 COPPERSMITH: Yeah, when we got into passive corrosion
22 or passive dissolution, and then we quickly--David talked
23 about the fact that we may--other things that occur there
24 that may not be strictly dissolution that sort of build up,
25 recrystallization of titanium and breakdown of that crystal

1 layer. It may be something that happens over longer time
2 periods.

3 And this is where we talked a little bit about
4 whether or not these are measurable in a reasonable period of
5 time, these types of processes. We had Digby suggesting
6 maybe, in fact, they could be. They maybe resolved ability
7 to--

8 SHOESMITH: There are experimental methods to play
9 around with passive films and get some feel for it. It's a
10 bit more fundamental and speculative than most of the other
11 research needs that we put down.

12 COPPERSMITH: Very long-term stability seems to be
13 coming up in a lot of this. Possibilities of defects. There
14 are part of that phase changes. How do we deal with that
15 long-term stability issue? I guess at this point it's
16 identified as a need. I'm not sure the tool has been
17 identified that would give us the ability to do it. It's a
18 wonderful part of a brainstorming session. We don't have to
19 say how you do it, just say this is a key need.

20 Residual stresses for fabrication enclosure.
21 Basically, Dan isn't worried at all about that, but that's an
22 issue. I think we need to look at that issue. There may be
23 a cost benefit or just a decision about the relative
24 importance of heat treating, post weld heat treating versus
25 increasing temperatures within the package.

1 Radiolysis, it sounded like David Shoesmith has an
2 opportunity to develop a publication that would summarize the
3 types of studies that have been done in this area. It isn't
4 necessarily one that needs to be addressed with
5 experimentation at the present point.

6 Then we got into different types of designs,
7 corrosion resistant materials over a structural material of
8 some type. The issue of handleability came up. How does
9 this translate into a research need isn't clear, I guess, but
10 it is an issue that was talked about.

11 I guess, you know, when we deal with not only
12 handleability, but some of the other mechanical criteria,
13 those seem to be very important criteria. I would assume
14 those are being anticipated for licensing and probably should
15 be given in the course of this analysis. But, you know, Joe
16 talked this morning that if we're worried about that
17 mechanical part, maybe having smaller canisters will be one
18 way of minimizing the weight and reducing the mechanical
19 constraint.

20 A mixed metal crevice, again, I'm not sure if that
21 was a research need, but it was identified as a potential
22 issue that might affect some of these alternatives where
23 we're dealing with titanium and C-22.

24 PAYER: That's a research need, the susceptibility of
25 crevice corrosion of all those combinations.

1 COPPERSMITH: Of the crevice--all the combinations.

2 PAYER: Yes.

3 COPPERSMITH: Okay. Is that one that is amenable to
4 experimental treatment?

5 PAYER: Absolutely.

6 COPPERSMITH: So you actually create those types of
7 environments, look at their stability and so on?

8 PAYER: You get them growing however required. You
9 bring them back to more realistic conditions, look for the
10 stifling.

11 COPPERSMITH: Fabricability, especially of C-22 and
12 titanium. This is in a group that does a lot of fabricating,
13 but I think it was identified that some of these--there may
14 be some constraints. I know I don't do much fabricating
15 other than showing geologic stories.

16 The tuff metal crevice, and this contact, I guess,
17 in this crevice is something that needs to be evaluated
18 experimentally to really look at the--and Alberto had some
19 ideas about how that should be done.

20 Let's see, the interaction with the supports. We
21 have a pedestal-type structure right now. It's assumed to be
22 a carbon steel, but that--again, that potentially with a
23 corrosion resistant material on the outside, you need to
24 consider the supports and that contact of potentially that
25 crevice.

1 The choice of the structural material, this is the
2 idea of some of the alternatives that exist, whether or not
3 we should be dealing with stainless steel, carbon steel.
4 Again, those issues I think we've sort of said that this is
5 something that needs to be evaluated and have not really
6 dealt--I think this group deals more with the corrosion
7 aspects than the structural integrity aspects.

8 Residual moisture in the container; everyone knows
9 they're going to be perfectly dry, so that's a non-issue.
10 But someone might need to look into that more detailed. I
11 haven't heard any discussion of that. I've always assumed
12 that this first penetration was going to be quite a bit of
13 moisture that works its way in through human air conditions,
14 if nothing else. But I guess for some of these processes, it
15 may be important to know the amount of moisture after the
16 canister is closed.

17 MACDONALD: The calculation has been done for it. I'm
18 just trying to remember where it was done, but the general
19 conclusion, as I recall, is that there's not enough--you can
20 never get enough moisture from an ambient air, okay, to cause
21 yourself any serious damage. But that calculation has been
22 done for--it was part of the AECL.

23 SHOESMITH: Yeah, but there is a slightly different
24 issue here. What do you have in the failed fuel bundles?
25 You know, are you going to put in a water-logged fail to a

1 fuel assembly? That's another issue. It was calculated also
2 by Dr. Sharland for the inter-carbon steel container that
3 they were thinking about. It might be a specific issue just
4 for titanium because it can absorb some hydrogen at those
5 high temperatures.

6 PAYER: But that does impact on the zirc clad there,
7 also.

8 SHOESMITH: Yes, exactly, to soak it up.

9 COPPERSMITH: Someone may know just quickly if that's
10 already being done. Is that internal moisture?

11 SPEAKER: We need some analysis.

12 COPPERSMITH: Okay. Then we moved on to the Number 4,
13 which was a C-22 on a cast steel design. I guess--I'm not
14 sure if it was a real issue, but Carl put it down anyway, the
15 cathodic aggravation issue. And it sounds to me like
16 experimental work needs to be done on cathodic aggravation.
17 But anyway, I guess the idea is whether or not, in fact, that
18 combination in that configuration is actually worse than
19 otherwise. I'm not sure.

20 Let's see, then we got into the idea of wall
21 thickness, and I think what that is, is just a surrogate for
22 what we had a lot of discussion about, is the idea of how
23 deep can pits actually propagate, how do they repassivate.
24 Ultimately, what is the mechanism or really the model that we
25 use to capture growing localized corrosion or general

1 corrosion. You know, we know now that a lot of pits die
2 along the way. How do we use that information in a
3 performance assessment type model ultimately is going to need
4 to be done.

5 But in the same way, right now, general corrosion
6 is the dominant corrosion is the dominant mechanism for these
7 materials. You know, what benefit do we get by adding
8 another centimeter of these I think is sort of the area that
9 we need to look at.

10 Then the issue of corrosion products, are they
11 protective? Can you transmit water through them very easily,
12 readily? We didn't deal with the transport of radionuclides
13 out of them. That's something that others have thought may
14 be an interesting problem to deal with. But just the
15 corrosion product issue, their ability to protect or not, I
16 think is an issue that needs some type of pursuit. I'm not
17 sure if any recommendations were made for how that might be
18 done, other than developing those corrosion products and
19 looking at their characteristics.

20 Nature of growth laws for titanium C-22; again,
21 there's a little bit of overlap, and there's about three
22 issues that are all sort of tied up in that same one. What
23 do these things look like, and, you know, what someone like
24 John would say is, yeah, yeah, yeah, they give me an N-value.

25 Ultimately, we know there is growth laws to these

1 things. I was amazed, by the way, to look at your damage
2 functions. Those look just like the frequency magnitude
3 relationships for earthquakes.

4 MACDONALD: Look just like what?

5 COPPERSMITH: Frequency magnitude relationships for
6 earthquakes. Magnitudes 7s and 8s in those rare events, they
7 occur very infrequently, smaller magnitudes, and they follow
8 very strict laws that look very much like that. So, I mean,
9 self-similarity. Must follow--must be deterministic because
10 it follows a natural law.

11 Okay. Now we went on, let's see, submergence. I
12 guess you were starting to write more rapidly here. It sort
13 of looks like it was a parazac comments, submergence or a
14 portion--

15 PAYER: In the vertical boreholes--

16 COPPERSMITH: Oh, okay. Yeah, I think one of our
17 problems, what I see here is we start with an unsaturated
18 site in our ability to rely on. So we put it in vertical
19 emplaced boreholes, put bentonite around it and assume that
20 it's going to be wet. Now we need a system that ensures that
21 it stays wet.

22 SPEAKER: Sprinklers?

23 COPPERSMITH: That's fine under the water table, it
24 happens a lot, but here it becomes a little bit difficult to
25 do.

1 PAYER: The idea that roof drips would accumulate and if
2 it had a cool temperature it would just go down seeking
3 outlets, but it could get trapped in a low permeability
4 portion of a borehole and just sit there.

5 COPPERSMITH: Phase stability issues, particularly C-22
6 and near welds and other areas like that that have been
7 affected is a potentially important issue, and I imagine--I'm
8 not sure how those types of issues are handled, if they're
9 analytically dealt with or experimentally dealt with for
10 things like C-22.

11 It sounds like--pardon me? Cook and look? Oh,
12 boy. It is getting late here.

13 Post-weld heat treatment. Over lunch Dan changed
14 his mind. Said that it just isn't worth it. Doesn't want to
15 sizzle the cladding. Basically we won't need to do that.

16 BULLEN: Not.

17 COPPERSMITH: This is not only an issue of sort of
18 tradeoffs, but it is one that can be evaluated in that
19 context. Nothing wrong with that.

20 Then the whole issue of heating, do we go beyond
21 350 not only because of cladding, but do we get into other--
22 as Joe says, other issues then arise. Analyzability becomes
23 potentially more of a problem in being able to sort of show
24 that, well, we're now at 400 degrees or whatever, different
25 types of processes might kick in at those temperatures.

1 Let's see, describing future events, if you can do,
2 taken in principle can model. This is Digby's--boy, this is
3 right up to the minute. He just said this a minute ago. A
4 real problem is modeling future events, is the knowledge of
5 future events. I agree with that.

6 MACDONALD: Specifying future scenarios.

7 COPPERSMITH: Okay. Is that something that we should do
8 something about or just worry about over the course of the
9 next--

10 MACDONALD: Might get in the next religious.

11 COPPERSMITH: Okay. Actually, I have some people that
12 were on some of these panels to look at future civilizations,
13 and it's a very, very difficult problem of modeling even past
14 behavior and why you did things that were done.

15 MACDONALD: I mean, who 200 years ago would have thought
16 that we would be trying to bury nuclear waste.

17 COPPERSMITH: That's true.

18 SHOESMITH: What is the meaning of life anyway?

19 COPPERSMITH: I don't know, but we've got to catch a
20 flight, so we'll have to discuss it on the way.

21 Finally, natural analogs came into--and again, this
22 arise in the waste form area, too. I think in a number of
23 places we would like to appeal or make a forward prediction,
24 if you will, over thousands of years. We'd like to appeal to
25 those things that extend back in time, a comparable or some

1 reasonable portion of the time period that we're trying to
2 look forward. And again, it's very difficult because nature
3 --like I said, even civilization didn't do much when you go
4 back a few hundred years. And it isn't clear how much we can
5 use from the past, but that's something that we constantly
6 need to take into account.

7 As a geologist we use it every day. I mean, I
8 don't provide an estimate of earthquake hazard to a city
9 unless I look back several thousand years in the geologic
10 record to see what's happened in that time period, and that's
11 for a short future.

12 In fact, in the seismic hazard analysis, you might
13 feel good to know that the pattern of earthquakes that were
14 evaluated in all of the investigations and so on occurred
15 over the last approximately, oh, 200 to 500,000 years. And
16 it's that record, as poorly resolved as it might be, that was
17 used to make predictions over say the next 100,000 years.

18 So they were over comparable time frames, and that
19 may be the--volcanism, kind of the same thing. But those may
20 be the only areas where we have that sort of record.

21 Okay. So, Carl, I'm not sure what your plan is on
22 these. But one thing, I wanted to make a point. Some people
23 were asking the question whether or not we should prioritize
24 these and so on. I think we're not in a position to do that
25 right now, obviously, given the fact we just had a chance to

1 talk about these things for a couple of days.

2 But what would be done, I think, in making
3 decisions in prioritization would be to really develop a set
4 of evaluation criteria, say, okay, we're going to deal with
5 all these issues of cost and weldability and mechanical
6 strength and corrosion resistance and so on, and evaluate
7 their relative importance first. And they become, then, the
8 template or the tools that's used to evaluate some of these
9 research needs. And then they are evaluated one by one, and
10 that's rolled up into decisions about what gets carried
11 forward.

12 Some of the issues that I think are important to
13 evaluation are ones that are beyond the scope of people here.
14 Some of the cost issues, obviously, came up, some of the
15 fabricability issues and so on. But those issues all should
16 be rolled into an assessment of future priorities for what
17 should actually be carried forward.

18 I don't know if you have any other comments you'd
19 like to make, Carl.

20 DI BELLA: I know that Alberto--

21 COPPERSMITH: He's going to wrap up. But these--I
22 enjoyed the process going through this. I think it's been
23 very valuable for me. This is a great panel. It's too bad
24 this isn't an Expert Elicitation Panel because I'd love to
25 get some real distributions out of you guys. I've already

1 done it from that guy.

2 SHOESMITH: How many shots at me do you want?

3 STREICHER: Do you want to rank these by the potential
4 for producing useful information?

5 COPPERSMITH: They can be ranked, as I mentioned before,
6 by a number of different criteria. And I think you need to
7 deal with the Board in terms of how they would like you to
8 respond. But I think, for example, that considerations of
9 cost in this discussion have been fairly minor. Issues of
10 your ability to be able to carry out a particular research
11 activity or conduct an experiment are vital and would need to
12 be considered and evaluated. I think there's a number of
13 ways that they ultimately need to be evaluated.

14 STREICHER: I mean, to what extent are we asking the
15 impossible?

16 KESSLER: That's what I was going to say. I think that
17 it would be fair for this panel to make some statements about
18 what of that list seems doable and over what time frame,
19 leaving aside the prioritization of how you trade off cost
20 versus something else, which I readily--I mean, I fully agree
21 is beyond the scope of this panel.

22 COPPERSMITH: Again, I haven't laid out the scope for
23 the panelists here, but I would strongly recommend to the
24 members of the Board that that--if you are guys are willing
25 to do that, to make your assessment of how doable these are,

1 what problems there might be in carrying out and addressing
2 these research needs, it seems to me that would be excellent.
3 It could be based on this list.

4 BULLEN: I guess the question I have with respect to
5 what the panel might think is, we spent a lot of time talking
6 about Option O, which is the base case design, and then we
7 came up with other options. Do we feel that these options
8 are equal to or better than zero, or is zero good enough, or
9 should we leave well enough alone? Don't want to do that?

10 KESSLER: I don't want to do that. I don't think you
11 want to do that.

12 BULLEN: Okay. We just wanted to put the platter out
13 and let DOE choose.

14 KESSLER: You can't just confine this issue to
15 corrosion, Dan. I mean, there are a bunch of other issues
16 that get involved that are way beyond--

17 COPPERSMITH: Well, and I think when we started talking
18 about research needs, you saw that a lot of them cross over
19 designs. I think you want to have--

20 BULLEN: And cross over issues that we don't have to
21 discuss here.

22 COPPERSMITH: Well, true, exactly, and I mean, all the
23 environmental issue that affects this is key. I don't know,
24 it's nice to think of a process where research needs are
25 addressed that, in fact, have more general applicability to

1 broader ranges of design concepts, and I think that's what
2 sort of happened.

3 SHOESMITH: With anything that we write, we may make
4 comments on what we think is important or easy, but I don't
5 think it's right to come up with a hard and fast prioritized
6 list without those people who are affected by it having a
7 chance to be involved in the discussions.

8 BULLEN: I agree. Yeah, that's a good point.

9 COPPERSMITH: And I think, you know, some of these
10 issues have cost, and other things will come into play,
11 obviously. That's why we agreed over lunch that we would not
12 force this group into a prioritization because there just are
13 a number of issues that need to be thought through.

14 Dan, you look disappointed. It looks like you'd
15 like to be able to prioritize.

16 BULLEN: No, no, actually I only had one other issue
17 that I wanted to talk about, and that's the concern that I
18 have with respect to the 350 degree C temperature limit for
19 cladding.

20 KESSLER: A validity issue?

21 BULLEN: No, well, I guess the concern that I have--

22 KESSLER: --the validity of 350 C over a long time.

23 SPEAKER: It's on there.

24 BULLEN: But the concern that I have is that the
25 fundamental bottom line that DOE ties to the 350 degree C

1 limit is the clad credit that they take in the base case, and
2 I have a group of experts here who I'd like to draw upon to
3 say do you buy that? Do you buy the DOE base case of clad
4 credit, and if so, why? Convince me, because I don't.

5 COPPERSMITH: But that's not even a waste package issue.

6 BULLEN: It's a waste package issue with respect to
7 fabricability because if you've got to tie the clad credit--

8 COPPERSMITH: The cladding credit, per se, becomes a
9 performance issue.

10 BULLEN: If you take it out of the base case, it's not a
11 barrier in the engineered system. It's just a release or an
12 egress limiting step, which I'll let them have.

13 COPPERSMITH: But its effect is on dose.

14 BULLEN: Right.

15 COPPERSMITH: Right. So it's really a--it's a
16 performance assessment issue.

17 KESSLER: No.

18 BULLEN: No, it's an engineered barrier issue.

19 KESSLER: Yeah, absolutely. It's a barrier.

20 BULLEN: It's an engineered barrier issue.

21 KESSLER: The way they're treating it is a barrier.

22 BULLEN: They're treating it as a barrier, so it's an
23 engineered barrier--and it wouldn't bother me if they had
24 presented it at the presentation two weeks ago in saying that
25 it's an egress barrier for the release. But they put it in

1 as an engineered barrier. And so if they're using it as an
2 engineered barrier, I've got a question of its validity.

3 KESSLER: It's fair game.

4 BULLEN: And if they put it in as an engineered barrier
5 and say that they've got 2 per cent of the cladding that's
6 intact up until 60,000 years and 10 per cent of it is intact
7 up to a million years, I would kind of like to ask these guys
8 if they think that's true.

9 PAYER: Parking lot.

10 BULLEN: Okay.

11 COPPERSMITH: I think it's time to reconvene a--

12 BULLEN: Waste form degradation?

13 COPPERSMITH: Something like that. I think it's much
14 more along the lines of--

15 SHOESMITH: This may not make it to a parking lot. It
16 might only make it to a parking meter, but--

17 BULLEN: No, I guess that's just the issue that raises
18 itself because I'm very constrained by the 350 degree C
19 temperature limit, have been since 1986 when I wanted to post
20 weld, heat treat 304L stainless steel containers that were
21 going in boreholes, and they wouldn't let us do that either.

22 KESSLER: For post weld heat treat, you're constrained.
23 If you talk about some of the other temperature scenarios
24 with the 200 C wall limit and things like that, I think you'd
25 agree with some of the--

1 SAGÜÉS: Again, I didn't know if we could go into
2 another issue, but--

3 BULLEN: I'm done, that's fine.

4 SAGÜÉS: All right. I guess that we were going to ask
5 DOE about one or two of these areas that we identified as
6 needing research, what was being done at this time. And I
7 specifically--I don't think that we heard yet about the
8 predictions of the chemistry of the environment that were
9 being contact with the package, and I want to turn it on to
10 effectively the thermodynamic predictions of what would be
11 the pH and the chloric content and so on of J-13.

12 COPPERSMITH: We have that in research needs.

13 SAGÜÉS: Yeah, I know, but at the DOE--

14 COPPERSMITH: In terms of what's going on right now?

15 SAGÜÉS: Right, right.

16 STAHL: Stahl, M & O. We have done some calculations.
17 Actually, Greg Gdowski has done that in preparation for the
18 long-term corrosion facility test where we've looked at 10X
19 and 1000X J-13. He's also recently done some calculations
20 looking at the molarity at more concentrated solutions.

21 What we want to do, and as I mentioned earlier, we
22 are currently starting to do, is drip tests onto heated
23 surface where we're going to be examining the electrolyte
24 chemistry as a function of time.

25 SAGÜÉS: I see. How about surfaces that would have,

1 like for example, steam shavings or some such iron, that
2 result in corrosion products? So what happens with the
3 concentrated J-13 water in the iron itself?

4 STAHL: We're doing a little bit of that in the relative
5 humidity chamber tests where we're looking at the buildup of
6 the oxide scale as a function of temperature and relative
7 humidity, and there are differences depending on the
8 condition.

9 SAGÜÉS: Sorry. I was just kind of talking to this
10 and--

11 STAHL: That's okay.

12 SAGÜÉS: Yeah, effectively what I'm saying is, is taking
13 J-13 water and dripping it into hot iron shavings and letting
14 it evaporate, to observe effectively, what would be the
15 terminal pH chloric content and so forth?

16 STAHL: Yeah, we are doing a related experiment. That
17 is, we will actually corrode the carbon steel that's on a C-
18 22 specimen. So we will have that interaction of the
19 concentrated J-13 with the corrosion products and the
20 crevice, or the start of the crevice.

21 SAGÜÉS: I see. And how about using crushed tuff?

22 STAHL: Not in this work. We are doing some things on
23 the EBS side, looking at the interaction of effluent from the
24 package on crushed tuff and degraded concretes, but it's not
25 --we're not looking at the influx of water.

1 SAGÜÉS: I see. And any other--any additional modeling
2 computations, like looking at the thermodynamic properties
3 and seeing what evaporates?

4 STAHL: Yes. Greg, again, has looked at some of the
5 thermodynamic information with regard to the iron oxidation
6 products, and he's prepared that with what we would expect--
7 excuse me, what we'd actually see in the tests. So there's a
8 little bit of that being done, but not a heck of a lot,
9 frankly.

10 DI BELLA: Dave, both you and Dan have mentioned that
11 you're dripping J-13 water onto the heated surface. What
12 actually is the heated surface? Is it steel, or is it
13 something else?

14 STAHL: It's a two-inch heated tube, and I don't
15 remember the material of the tube, whether it's a stainless
16 steel or not. Dan has taken off. But what we do is actually
17 put other specimens on top of that heated tube, so it heats
18 the specimens by conduction. And that's what we look at, the
19 specimens themselves, not the heated tube, and I think the
20 heated tube is just stainless steel.

21 STREICHER: Could you accelerate that by using not the
22 J-13, but highly concentrated J-13?

23 STAHL: We can. That's a possibility. I'll have to
24 check with Greg, but he will be concentrating the dripping
25 water by elevating the temperature of the tube. So he'll get

1 some flash evaporation as Digby was mentioning earlier on.

2 COPPERSMITH: Any other questions? Yeah, Mike?

3 STREICHER: Could you go around and ask again the
4 various mechanisms whereby ferric chloride could appear in
5 the absence of radiolysis?

6 COPPERSMITH: Who should I ask? Who wants to answer?

7 MACDONALD: Ferric chloride could appear in the absence
8 of radiolysis?

9 STREICHER: That's right.

10 MACDONALD: Mike's scenario, on the carbon steel?

11 STREICHER: Yes, if we had the carbon steel on the
12 outside.

13 MACDONALD: Sure, if you--I mean, just evaporation--
14 corrosion and evaporation. Any cations in the--particularly
15 highly-charged cations, of course, hydrolyze to give you a
16 lower pH, and so the solubility of iron oxides increase. And
17 if you concentrate the chloride in there, the cations become
18 even more stable at high temperature because it conflicts
19 with the chloride.

20 You know, if you look at the potential pH diagram
21 for iron in a chloride solution at high temperatures, the
22 stable dissolve species very quickly becomes FeCl_3 , zero
23 because what happens is the chloride ions counteract the
24 charge. The irons don't want to be in high temperature water
25 because the dielectric constant has dropped so rapidly.

1 So you tend to get complex species at higher temperatures, so
2 FeCl_3 , zero, the dissolve species, perform. And when you cool
3 that system down, you've already got soluble iron and the
4 presence of a lot of chloride. So I can easily see a
5 mechanism for full measurement of ferric chloride.

6 STREICHER: Basically, the accumulation of chlorides
7 from the J-13?

8 MACDONALD: Oh, yeah. Actually, the stuff we did for
9 Peter Miller shows that in a boiling crevice, which is
10 comparable to a boiling porous deposit, what happens is that
11 depending upon the super heat that you have, you generate a
12 simmering phase. The concentration will build up until you
13 annihilate the super heat, and then you essentially get a
14 stationary concentrated phase. And that stationary
15 concentrated phase essentially fills most of the crevice, and
16 it's just up to about 90 per cent of the crevice. And so you
17 end up with a very concentrated solution, chloride solution.

18 But I emphasize again that the pH that you end up
19 with depends in a very sensitive manner on the identity of
20 the cations in the system and the ratio of certain cations to
21 anions. And EPRI is trying to use that idea at the moment to
22 drive all of the steam-generated crevices in one direction or
23 another in operating plants.

24 It's not a trivial problem to deal with this.

25 STREICHER: Yeah, one reason I ask is I talked with Mr.

1 Ahn from NRC the other day, and he said essentially the
2 absence of radiolysis, he wasn't worried about ferric
3 chloride. And he used diagrams to elaborate on this.

4 And I think, you know, there's an important point
5 here. Where are we going with ferric chloride problems? Are
6 there some or are there none?

7 COPPERSMITH: I don't think we've identified that as a
8 research need.

9 STREICHER: David, you had.

10 SHOESMITH: I don't think radiolysis is necessary to get
11 ferric iron. I think radiolysis will regulate ferric iron.

12 CRAGNOLINO: It's a comment regarding this point. In
13 the solution of iron, a-- gives you iron two. But in the
14 presence of oxygen, you have this reaction of oxidation in
15 the liquid phase. The question that--iron three speciating
16 solution will turn up again upon the pH of the environment
17 that is contacted and Digby said about the available
18 concentration of chloride because you have a relatively high
19 concentration of chloride. You can stabilize iron chloride
20 complex instead of having the precipitation-- of the higher
21 oxide species.

22 COPPERSMITH: Alberto, I believe you're in charge of
23 wrap-up of our session here.

24 SAGÜÉS: Well, yes, do we have any other issues? We
25 still have 14 minutes. Do any of the members of the panel

1 have any pressing matter to say?

2 BULLEN: If you'd give me a chance, I would like to
3 thank everybody at the table because this was a great
4 interaction. On behalf of the Board, Alberto and I both
5 think this is a wonderful opportunity to pick your brains
6 because I mean, that's why we bring experts in, and you've
7 been a great help to the Board in its deliberations with
8 respect to waste package and waste package performance.

9 SAGÜÉS: Yeah, please go ahead.

10 STREICHER: Somewhere today, somebody mentions 304L,
11 again, for something inside the container. And the comment
12 is, if you must, then maybe grit blasting will help with the
13 stress corrosion problems, and I think it's possible that
14 grit blasting could be carried out on containers containing,
15 you know, radioactive material and devices might be developed
16 to do that without people getting near.

17 SAGÜÉS: Well, I don't have a script, so I'm going to
18 have to--this message will be very short.

19 First, I would like to thank Kevin for the
20 excellent job that he has done in coordinating everything,
21 and again, thank all the participants and also those in the
22 audience that have had the fortitude to stay until this hour.
23 I think that Kevin made a very good summary of using the
24 notes that Carl has that he prepared throughout the meeting.
25 I personally have learned a lot, and I hope that this has

1 been an exercise in trying to find truth. There is quite a
2 bit of truth that needs to be found and that meetings like
3 this will help reveal.

4 We try very much to have an impartial attitude for
5 these alternatives that may exist. We certainly weren't able
6 to exhaust all of them by any means. But at least this might
7 help that this will bring a certain other element of
8 diversity to the technical approach that would help us deal
9 with our nation on nuclear waste disposal needs.

10 So having said this, thanks again to everyone for
11 their participation.

12 (Whereupon, the meeting was adjourned.)