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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON NUCLEAR WASTE & MATERIALS

February 12, 2008

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE AND MATERIALS

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186TH MEETING

+ + + + +

VOLUME I

+ + + + +

TUESDAY,

FEBRUARY 12, 2008

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, Rockville, Maryland, at 10:00 a.m., Dr. Michael T. Ryan, Chairman, presiding.

MEMBERS PRESENT:

MICHAEL T. RYAN, Chair

ALLEN G. CROFF, Vice Chair

JAMES H. CLARKE, Member

WILLIAM J. HINZE, Member

RUTH F. WEINER, Member

NRC STAFF PRESENT:

NEIL COLEMAN

DEREK WIDMAYER

LATIF HAMDAN

ANTONIO DIAS

CHRISTOPHER BROWN

DONALD COOL

TAE AHN

TIM McCARTIN

BRITTAIN HILL

ALSO PRESENT:

CHARLES FITZPATRICK (via telephone)

STEVEN FRISHMAN (via telephone)

KEITH AXLER (via telephone)

PAUL DiBELLA (via telephone)

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

10:02 a.m.

CHAIR RYAN: Come to order, please. The meeting will come to order. This is the first day of the 186th meeting of the Advisory Committee on Nuclear Waste and Materials. During today's meeting the Committee will consider the following; discussion of ACNW letter reports, recommendations by the International Commission on Radiological Protection in their Final Report 103, Corrosion of Waste Package and Spent Fuel Dissolution in a Repository Environment.

Neil Coleman is the designated federal official for today's session. And Antonio, until he gets here, you'll be the designated federal official, if you please.

ANTONIO: I'm here. Okay.

CHAIR RYAN: All right, Neil Coleman has just arrived. We have received no written comments or requests for time to make oral statements from members of the public regarding today's sessions. Should anyone wish to address the Committee, please make your wishes known to one of the Committee staff.

It is requested that speakers use one of the microphones, identify themselves and speak with sufficient clarity and volume so they can be readily

heard. It's also requested that if you have cell phones or pagers, you'd kindly turn them off at this time. Feedback forms are available at the back of the room for anyone who would like to provide us with his or her comments about the meeting.

Without further delay, I'll turn over the meeting to our cognizant member, Professor Hinze, who is going to lead us in a discussion of the Committee Letter on Post Closure Degradation of Emplacement Drifts and its Impact on Engineered Barrier System Performance at the proposed Yucca Mountain High Level Radioactive Waste Repository. Professor Hinze.

CHAIR RYAN: For this portion, we will go off the record. We don't need to have this letter writing on the record. We'll reconvene the record at 1:00 o'clock when we pick up on the ICRP work. So with that, we'll close the record at this point. Thank you.

(Whereupon, the record was recessed to reconvene at 1:00 p.m. the same day.)

(On the record at 1:01 p.m.)

CHAIR RYAN: All right, if I could ask everybody to come to order, please. We will go back on the record for our afternoon session. And our first -- is there anybody on the bridge line, please?

Anybody on the bridge line? Nobody is there, okay, that's fine. They'll beep when they come in and I might interrupt you, Don, so we can get them to introduce if they do come in.

We'll hear from Dr. Donald Cool on the International Commission's Final Report 103 on basic radiation protection standards. Without further ado, Don, take it away.

DR. COOL: Okay, thank you, Mr. Chairman. We have interacted often as the International Commission on Radiological Protection has worked its way through the extended process of developing its revised recommendations. I'm here today to give you a brief overview of the conclusions and see if we can make the computer work. Sure enough. Okay. ICRP Publication 103 made available on December 18th of 2007. If you go to ICRP's website, there's a little announcement. If you click on that, you get a little word document which tells you the various and sundry places where you can buy it or download it, et cetera.

So it is now available and out there for discussion and use. The report is just a small document. This is printed double-sided, 332 pages or so counting the appendices. I would note that a good half of these, you can see where the red tabs are part

way through this, a good half of it is appendices material which actually supports the text of the recommendations themselves. What I hope to do in cumulus today is just briefly remind you of the things that are in there and quickly go over the extent to which the NRC's comments did or did not influence the draft and then briefly talk about the next steps as the staff moves forward now that ICRP has completed its particular piece of the work.

ICRP Publication 103 has an introduction, chapters related to the aim and scope of the recommendations, biological aspects, the quantities, system of radiological protection, the implementation of those recommendations, medical exposure, protection of the environment and then two annexes, one related to the health risks attributable to ionizing radiation and one related to the quantity. Those two annexes were last seen when the staff commented on early drafts of them several years ago when they were published as independent foundation documents.

In fact, we had not had a chance to review and comment on them for more than two years. So, we're still in the process of sorting through all of the information that's in there, so I'm just going to give you some sort of general observations today.

Main features, not particularly surprising because we've known mostly what was in the draft for a considerable period of time. They updated the radiation and tissue weighting factors. They maintained the three fundamental principles, justification, optimization and dose limitation.

You'll recall from our earlier draft there had been a much shortened discussion on justification. That has been re-elaborated some as we move to the final draft and this final version. They moved to a situation based approach. As in three fundamental exposure situations, a planned exposure situation, any time you're planning to do something, most everything that we would license here falls into that category; an emergency exposure situation where it's gotten out of control and you need to do something now, typical emergency planning type activities and existing exposure situations. It's out there, you sort of trip across it or decide that you now need to do something about it. It may or may not have been under control previously, et cetera, but it now has to be dealt with in some form.

CHAIR RYAN: Don, let me just if I may, I think the tissue weighting factors is really a technical calculational thing and I understand that

but I still struggle with your second and third bullet in that I don't see anything different other than terminology for the way radiation protection practice is laid out, not just in 10 CFR 20 but in all the other guides and foundation documents and all the rest that go with that. Am I off base on that comment?

DR. COOL: Most of it is the way of looking at things and explaining things. You're correct. The three fundamental principles, that hasn't changed at all.

CHAIR RYAN: Right.

DR. COOL: That fundamental approach has been and continues to be as it is in Part 20 and --

CHAIR RYAN: Yeah, but justification, optimization and all those terminologies from ICRP, you can look at ALARA and, you know, all the other kinds of terminologies that we use. I seen nothing different in practice --

DR. COOL: Correct.

CHAIR RYAN: -- other than what you call it. Okay. Thanks.

DR. COOL: And there they didn't even really changes what they called it.

CHAIR RYAN: What they called it but again, I'm not worried about what they're calling it.

What I'm saying is that nothing in this latest final document would change the view that we could show a one-to-one correspondence of what's done in the US using our terminology compared to what's done under ICRP with their terminology.

DR. COOL: Correct.

CHAIR RYAN: Okay.

DR. COOL: Correct. They've reinforced optimization with constraints. And this is a place where depending on where you are in the United States, what kind of licensee you're talking about, it's a description of the way things are done or it's a description of how we might wish they did things but they don't necessarily do it that way. Let me explain.

If you are in the nuclear power industry, then what they have here with constraints and optimization is exactly the process that any of the nuclear power plant radiation protection programs behave. They set facility specific activities values to make --

CHAIR RYAN: Excuse me, Don. Is that somebody who joined the meeting?

MR. FITZPATRICK: Yes, Charles Fitzpatrick, State of Nevada.

CHAIR RYAN: Welcome, Charles. Thank you, go ahead, Don.

DR. COOL: So a power plant will establish some specific value that they do not plan to exceed and then they will work their ALARA optimization process to try and further improve on that dose. That is exactly what a constraint and optimization is. So this is a well-established practice for a large organization. You do not find that kind of discipline and thinking in many of the smaller activities. You may find some measure of optimization in medical facilities and things. You find radiographers just basically trying to do that job out there.

So if you look at it in the context of our regulations, some licensees do this, some licensees don't. Moving on --

CHAIR RYAN: I can't imagine an all ICRP invoked countries that they're all doing the same level of optimization at all those areas either. There's nothing probably much different.

DR. COOL: No, no, what you have here is ICRP moving the recommendations and the description recommendations in part realigning with what has become very good practice and the approach to really doing a good job in radiation protection. So when

you're doing a really good job, this brings no new information or value to the table. The point I'm simply trying to make is that there are other places, both here and in other parts of the world where that higher level of approach and that kind of thinking has not yet become the status quo of activities.

And they have included, as we have talked about many times, an approach for developing a framework on protection of the environment. We will be back with you on Thursday afternoon to talk about a draft report that the ICRP has for comment right now which talks about this developing framework and reference animals and plants.

CHAIR RYAN: Let me throw a question out that maybe you'll handle later in the week. This document, the ICRP 103, says that you're not going to put a -- develop a formal system of dose calculations for non-human species but that's exactly what 103 does.

DR. COOL: It says they're not going to establish dose limits.

CHAIR RYAN: Dose limits.

DR. COOL: Dose limits.

CHAIR RYAN: So why develop a system of calculating doses if there's going to be no limit?

DR. COOL: Well, in fact, I think if you look at their words, what they are saying is they are trying to put together a framework that would allow you to do assessment. We do assessments in the environment under the National Environmental Policy Act.

CHAIR RYAN: Sure.

DR. COOL: This is a mechanism to do assessments with an end point that isn't necessarily specifically linked to humans to allow you to demonstrate what protection is or isn't being afforded by some particular control --

CHAIR RYAN: Well, that's the theory of what they said it's supposed to do. You know, we'll talk more about that on Thursday.

DR. COOL: We'll go through this in detail on Thursday. We can have -- we can take the entire afternoon discussing this and I don't think we're quite ready to do that yet.

CHAIR RYAN: Fair enough. Fair enough.

DR. COOL: We have a whole other talk ready for you at that time.

CHAIR RYAN: All right, great.

DR. COOL: Okay. Let me spend a couple minutes and talk about the impact that NRC's comments

have had over this process. We have had many of our editorial and specific comments that have, I believe, directly contributed to significant improvement in the text. We've suggested lots of things. They've done a number of things. That's not to say that they did everything, nor did they necessarily do it the exact way we would have done it, something about American English versus King's English.

They have done a considerable effort to try and clarify constraints in their use because we raised a number of issues. As it was originally described, it did not seem to align with the way radiation practice was actually conducted. That has been much improved and we now have that alignment.

We very much wanted them to have the words in there about the use and the areas of inappropriate use for collective dose and those words are in there. Although they didn't go so far as we had asked them to which was to actually give us some quantitative guidelines for when you would or wouldn't use collective dose calculations.

CHAIR RYAN: What's missing on that score?

DR. COOL: Well, what you find in there is the lovely statement that collective dose should not be used for epidemiological purposes integrating over

all space and all time very small doses. What is not there is anything that would allow us to understand what the phrase "small doses" might be. So when you boil it down and as you were briefed the briefing or two ago by a researcher on the state of the art consequence analysis, a question of what small doses might it be reasonable to not include?

This would suggest to you that it's not reasonable to include those small doses but it doesn't give you any sort of help in actually sorting out what the small doses would be that you wouldn't want to include in the calculation. The ICRP unfortunately, has to rely on unpublished and non-publically available information. You'll recall that we had specifically commented to them that it really should have published sources available. This has gone ahead and moved forward on a schedule they had advertised and some of those materials are not yet available.

We had suggested to them that there were a number of the tissue weighting factors, particularly in the remainder category, which did not even seem to comport with that which we understood to be radiogenic. There were not changes in that so there are the 13 tissues that remain in that remainder category of tissues for evaluation. And we had

commented that we really thought that there was no need for the chapter on protection environment given that that chapter really didn't provide any recommendations. It simply said we're going to develop a framework and we're going to be looking at some things. So it doesn't contribute to the recommendations.

They've kept the chapter in. The good news is that it doesn't actually provide any recommendations. It doesn't give you something that you would actually want to go out and try to create a regulatory structure on it otherwise. It is a plan of work, as it was in the last draft.

Now, that the ICRP has completed its process, the NRC staff is initiating its effort to prepare options for Commission consideration. A number of years ago, go back to about 2001, actually, the staff actually went to the Commission to seek specific direction on whether or not to start proceeding at that time to look at a revision of 10 CFR Part 20. We recommended and the staff agreed that it would be better to wait for this ICRP recommendations process to be completed so that we could consider this material in any consideration of possible revision rather than being in the same sort

of context that we were in last time where we were essentially done with the revision of Part 20 when ICRP 60 came out in 1990.

Now that ICRP is completed, the staff has initiated its effort to go look at Part 20 and other regulations to determine what things might warrant update, what the options, what the costs would be associated with that, the impacts, the wide variety of things that we need to assemble to understand whether or not to suggest doing something and what the implications of that would be.

Now, I think it's safe to say that there are some things, changes to the weighting factors and some of the calculational material, which would certainly warrant a very hard look and probably updating. I would also note that there is considerable interest within the staff to try and update some of the regulations which were not revised at the time Part 20 was revised in 1991; for example, Part 50, Appendix I, which actually is the controlling factor for all of the reactor effluents and otherwise the underlying technical basis for that regulation and guidance is still ICRP Publication 2. So there's a considerable interest as we start to look to the licensing of the new generation of reactors and

otherwise to try and bring the entire suite of NRC activities up to a new point.

That would tend to argue that there will probably be some things that we will want to try and consider but I am not here today to give you any particular viewpoints on what will or will not be done because we have only begun the process within the staff and the various offices to try and catalog where all of those different bits and pieces are, what the impacts are to different groups, how you might construct an option that would minimize some of those impacts, what the impact of the backfit analysis and other would be associated with that and you can tick off any number of things that we will have to consider over the next 10 months or so.

The staff is due to go to the Commission with this options paper in December of this year. We have a lot of work to do.

CHAIR RYAN: Don, are you going to publish a plan of what you're going to do during this year? Is there an outline or a plan or some other document?

DR. COOL: There is at this point no published plan of work. I can't tell you that in March we will be thus far and in April thus far, no. The staff is just assembling the technical staff leads

to try and catalogue the data and work through that process.

CHAIR RYAN: You're sort of combing through and gathering 10 CFR 61 and all the other parts that are out of whack.

DR. COOL: Right, that's our first step in the process.

CHAIR RYAN: Does that cover the Reg Guides, too?

DR. COOL: Is to catalogue those and certainly the guidance, regulatory guidance and other things which are based on or derived from some of those regulations will have to be looked at because a lot of the impact and a lot of the cost of changing and updating is in those pieces not just --

CHAIR RYAN: Yeah, I was going to say, we looked at the Reg Guides in Division 8 and they are many Reg Guides --

DR. COOL: Correct.

CHAIR RYAN: -- that don't even refer to the numbers that -- I mean, the numbers they refer to are out of use, per section.

DR. COOL: Yeah, so the step one is to simply catalog the bits and pieces.

CHAIR RYAN: Right.

DR. COOL: All the tentacles if you will and then to try and understand how to eat this thing, bits and pieces, how large to make that, whether it's one large single effort, whether it's a set of parallel efforts, and I'll add another complicating factor on top of that which is in addition to the NRC looking at our requirements across the board, it's the coordination with the Department of Energy, the Environmental Protection Agency, Occupational Safety and Health, Department of Defense, FDA and others to try move in a consistent coherent fashion so that the Federal Government as a whole can be in a consistent position with regards to radiation protection.

We're not today, but that's the goal which we will try to seek. That will be done through the Interagency Steering Committee on Radiation Standards.

CHAIR RYAN: The rubber meets the road with the agreement states.

DR. COOL: And the agreement states.

CHAIR RYAN: So, I mean, that's where most of the licenses exist.

DR. COOL: Yes.

CHAIR RYAN: And then, of course the non-AEA regulation of medical and you know, other stuff that's out there that's not part -- I mean, if it's an

electronic product device, it's not regulated under the AEA but they've got to use the same system of --

DR. COOL: Circulated by the states.

CHAIR RYAN: Right.

DR. COOL: And for the most part what has been in Part 20 has been used by the states, certainly in the agreement states.

CHAIR RYAN: Right, because they're not going to make a separate rule.

DR. COOL: And they just apply it across the board.

CHAIR RYAN: Right.

DR. COOL: So there is a significant area there. We are planning to have state participation as we go through this catalogue of options development process. That's what I wanted to give you and I'll entertain other questions, if you'd like.

CHAIR RYAN: Could you talk a little more what the plan is with agreement states?

DR. COOL: The plan is to invite them have one, maybe a couple of state people participate in the staff working group that we will have to do the catalogue and to start to develop the options. This is the same kind of approach if this had been a more formal rulemaking workgroup which would have formal

state participation. It's not a rulemaking work group because we're not yet in the process of writing rule, but it's important to involve them in a similar sort way through a working group process in order for them to have input to the process.

CHAIR RYAN: Okay, Professor Hinze?

MEMBER HINZE: What's the title of this? I missed that.

DR. COOL: I probably actually didn't put the title on the slide. ICRP Publication 103, the 2007 Recommendations of the International Commission on Radiological Protection.

MEMBER HINZE: Thank you. And what -- I may be missing a good deal here but what are your requirements in terms of following these, of the NRC following these recommendations? What kind of legal or moral, ethical requirements are there for us to follow these recommendations?

DR. COOL: We have, by practice, tried to use the ICRP, NCRP various recommendations in the formulation of our requirements. There is no legal mandate that we incorporate ICRP recommendations into our regulations. Unlike the International Atomic Agency, which actually has a statement that they will try to be consistent with or incorporate to the extent

possible ICRP recommendations, they are a source of information.

The fact that something exists in these recommendations means that it is there to be considered within our formal Administrative Procedure Act rulemaking process. It does not mean that it must be or otherwise adopted. All of this will have to go through the process of consideration. It will have to go through public comment. It will have to go through analysis in terms of an Environmental Impact Assessment that would go through the rulemaking and back to the analysis all of those other bits and pieces.

But it certainly is an important piece of reference and in the existing environment where globalization is becoming more and more important and harmonization of regulatory requirements more important for organizations, licensees, who are doing business on both sides of the Atlantic and in Asia and otherwise, there is an increasing pressure, again, not mandate, that there be some consistency so that they're not constantly having to demonstrate compliance with multiple and different sets of values.

We see this in the nuclear power industry where the effort for vendors to compete

internationally is increasing their desire that the requirements here be the same as the requirements over there. You see it in their reaction when there would be an operational safeness review, an OSAR review of the IAEA where they raise questions about why the US standards are different. So there is a desire for there to be international consistency.

Again, that has not become a mandate. It becomes a piece of information that has to factor into the rulemaking development process.

MEMBER HINZE: Thanks, Don, that does help. I don't want to steal Mike's question, but if you have crystal ball, where do you see this recommendations or -- well, recommendations or statements about protecting the environment from radiation leading to? I mean, the clue to this chapter again, some very good advice. Get your crystal ball. What are we looking at here? What's this a first step? Is this just a -- is this just a twig that's grown off to the side or is this going to develop into something?

DR. COOL: That's a very good question. The crystal ball is very cloudy.

CHAIR RYAN: Good answer.

DR. COOL: If you polled a number of

people you would be N plus 2 views. My personal view of where I would like to see it move is to increase the technical information that is available that allows us to make assessments. Everything that has been observed thus far, information that is available, continues to support the general notion that the controls in place in existing planned activities, a licensee in terms of direct exposure situations, releases to unrestricted areas, are providing sufficient controls so that the environment in that area is protected.

The question would be, we have to, under NEPA, do assessments in the environment and otherwise and it would be very useful if this information could work in a way to support that which we must already do, which is to be able to do assessments and to be able to provide open and clear understandings of the basis for what we would do. I don't believe at this point, this is Donald Cool, not anybody else, that this information should lead to actual changes to the standards, but there are many who would wish to go there.

CHAIR RYAN: Bill, if I could jump in, you know --

MEMBER HINZE: I stole your question.

CHAIR RYAN: No, that's fine and I agree with Don's answer but, you know, I mean, there's 50 years -- 60 years of radiation biology that says if you protect man, you're protecting the environment and everything in it. I've asked the Chairman of the ICRP show me an example that's not true. He hasn't given me one yet. Now, I struggle with for example, I can calculate an absorbed dose to anything, the table, the cup, a crab, whatever I want to calculate it to, that's a physical quantity, but interpreting that in terms of rad to rem, that is what effect are you interested in, that's when I jump off the train.

So I really have a great concern that what is the assessment focused on. What we have done for 50 years, freight and transported radioactive material in the environment. There are folks who can talk about the benthic movement of plutonium, you know, for weeks. I mean, there's all sorts of information about freight and transported radioactive material in the environment. Some more than others, but I struggle with the intent and the use of these calculations, assessments, whatever you want to call them because I don't -- I don't understand what the end point is they're aimed at.

MEMBER HINZE: Well, what is the stature

of the technical basis for this 50 years?

CHAIR RYAN: I guess we'll hear that on Thursday. Oh, for the 50 years?

MEMBER HINZE: Yeah, that we've used for 50 years, what is the technical -- what is the stature?

CHAIR RYAN: Well, it starts out with, you know, everything from basic cell survival studies, right on through sophisticated radiation biology.

MEMBER HINZE: Do we have that codified in some way? Do we have that brought together in some singular fashion?

DR. COOL: I would suggest to you probably not in the way that you might be thinking. If I've written down someplace a scientifically document piece of evidence that says, "Yea, verily this is true that all of those have been protected"? No. That's part of the difficulty that environmental groups and others would constantly bring to your attention. All of the assessments have been based on linkages of radioactive material to various change leading to a dose to a human. There hasn't been any systematic or standardized separate assessment of a direct impact in the environment.

Now, part of that is because there are a

couple of fundamental questions which are not yet resolved. First you have to figure out who are you going to protect? Are you going to protect individuals? Are you going to protect small groups of individuals of something? Are you going to protect populations, over what size?

The second thing you have to sort of try and understand is, what are you going to protect them from? Are you protecting individual bees, they're one of the reference animals, from death or are you looking at survivals of hives or are you looking in general at the question of reproductive success of a honey bee in general in some area? Are you looking at morbidity, mortality, reproductive success? There are different measures.

After that you have to have sorted out the question of what kind of dose levels and what kind of radioactive material levels in their environment or in their bodies will get you to those effects? Those are three very important questions. We don't have the answers to any of those yet.

CHAIR RYAN: For any of the species they want to propose.

MEMBER HINZE: Right.

DR. COOL: So we have a ways to go.

CHAIR RYAN: There's another confounding aspect to this and you know, there are studies. For example at Chernobyl there was a very bright fellow that was from West, I think Washington State, maybe one of the universities out there that studied the ecosystem that's around Chernobyl, and because people have been removed from it, it's now more robust and healthy than it's ever been.

You're seeing the return of several mammals that have been long since gone and other things. I just found it fascinating. And, you know, his conclusion was that ecosystem is returning to health in spite of Chernobyl, but it's because people have been removed from the environment. So, you know, and again, I'm not saying that's a success story. By no means is it, but there's no pattern here of something as simple as let's describe the geology.

I mean, it's just -- you know, it's not clear to me how we're going to use these in referenced species other than to stay busy thinking about them. I don't see a goal or an end point but making an assessment using absorbed dose or some other physical, you know, manifestation of radiation interacting with some animal or plant, I don't understand where it's going to lead.

MEMBER HINZE: Well, should there be a certain level of studies that --

CHAIR RYAN: Well, there have been. I mean, there are decades. The Savannah River Ecological Laboratory has studied the 300 square miles at the Savannah River for 50 years. There's a mountain of work in the area of radioactivity in the environment.

MEMBER HINZE: But is that codified someplace, you know?

CHAIR RYAN: What do you mean codified?

MEMBER HINZE: Well, by codified, brought together so that --

CHAIR RYAN: Yes, yes.

MEMBER HINZE: -- one has a complete description.

CHAIR RYAN: Absolutely.

MEMBER HINZE: You know, because what I'm saying is that you go to a number of journal articles and that --

CHAIR RYAN: There are books and journal articles and studies and multi-year studies and 10-year summaries and all that kind of stuff that's out there. I mean, it is a robust body of literature as far as I'm concerned.

MR. HAMDAN: Mike, a couple of questions that Don raised, the three questions that there is, why nobody is addressing it?

CHAIR RYAN: What three questions again, I'm sorry?

MR. HAMDAN: The question he raised about who would be effected and what --

CHAIR RYAN: Thursday.

MR. HAMDAN: What they will be effected from and --

DR. COOL: We will talk about is more on Thursday. Let me give you --

CHAIR RYAN: But the answer is, those are very valid questions. I don't understand the basis for it. I have yet to understand the basis for it and I have not gotten a good answer from anybody either on the committee or involved with ICRP to tell me what the basis is.

DR. COOL: And I will not attempt to either. I will note to you that what ICRP Committee 5 has been working on has been to try and develop a framework with which to look at this one narrow question within the context of everything you have to look at from an environmental impact. When we do an environmental impact assessment or appraisal for a

facility, we just look at the wide range of impacts, what's the impact of the concrete, what's the impact of moving the dirt around.

One question relates to what might be the impacts of the radiological effluents and that has to be in the context of chemicals that are in the environment and everything else. This can be viewed as a small step in the process of helping to do that in a more systematic fashion. I'm not sure how much time we have on Thursday, but it's probably not enough.

CHAIR RYAN: Fair enough. Allen?

VICE CHAIR CROFF: Regarding collective dose, what does the report say about how to use or whether to use collective dose in I'll call it cost benefit analyses, like establishing the amount of effluence you can release of a stack or something like that? Does it get to that issue at all?

DR. COOL: What this report talks about is in general terms the appropriate uses, which are to compare options where you can define pretty clearly the set of assumptions, most easily described in the context of an occupational exposure. Do I do this work in this particular way with that kind of shielding and that respiratory equipment or do I use

a different kind of respiratory equipment? Which will give me better protection, and you can compare the dose to the group of workers doing it this way from this way and make a decision about what would be optimal.

Similarly, you could look at the various kinds of effluent technologies that might be available and understand what this technology costs and how much it reduces it versus what this technology costs and how much it reduces it. The context of using it for comparing options is a correct use. What this discourages is simply taking every bequerel that gets out and integrating the dose that you would get from every single bequerel to every single person that it might come into and believing that the combination of that multiplied by some risk coefficient, gives you a meaningful number.

CHAIR RYAN: Well, it's the old example of you don't want to compare a 100-mile an hour wind or 200-mile an hour wind for one hour and a two-mile an hour wind for 100 hours. The same amount of air goes by it.

DR. COOL: We also need to be careful between stochastic effects and deterministic effects.

CHAIR RYAN: All of that.

DR. COOL: So I just caution you on the example.

VICE CHAIR CROFF: I'm mostly interested in, I'll call it the public cost benefit as I've labeled it here, in saying that there is an appropriate use, do they give some guidance on how to go about it? You know, I'm remembering in one other ICRP report, they spoke to integrating over, you know, homogenous population groups and this kind of thing. Is any of that in this report?

DR. COOL: Some of that -- that material is not in Publication 103. There is some of that material and ways to look at the binning of various aspects of the dose and decision making which is actually part of Publication 101 related to optimization which came out last summer.

VICE CHAIR CROFF: Okay, that's the one I was thinking of.

DR. COOL: Yeah, that's the one you were thinking of and that also publishes -- it's one-half of Publication 101.

VICE CHAIR CROFF: Right, okay, thanks.

CHAIR RYAN: Ruth?

MEMBER WEINER: I'd like to take off from what Allen has just been asking because you mentioned

that there was something in this publication regarding the use of collective dose in comparing alternatives. Well, when you calculate collective dose, for example, in transportation, the collective dose is heavily dependent, in fact, completely dependent on the number of people punitively effected.

This is -- transportation along a route is a classic case of micro-doses to mega-populations. Does the document say anything or do you have any thoughts about when you get completely ridiculous answers. If you get a large enough population, you get a very large number of person-rem and even though we hear every day that the -- you apply some kind of conversion factor to this and the result is meaningless, nevertheless, this communicates something. Is there any advice in ICRP as to the limits of the use of collective dose or are you going to talk about this on Thursday?

DR. COOL: This is not a subject for Thursday.

MEMBER WEINER: Okay.

DR. COOL: And the answer is there are no quantitative suggestions for when it is or is not appropriate. There is the qualitative statement that it is inappropriate to use this complete integral of

collective dose for epidemiological or health risk purposes, but it does not give you any specific sort of indication of what a small dose or otherwise might be.

MEMBER WEINER: Has anyone ever brought to the Committee this consideration that if you have --

CHAIR RYAN: Which commission?

MEMBER WEINER: Don's commission, thank you -- the question if you have a large enough population, you're going to get completely unrealistic answers?

DR. COOL: This issue has been raised with the ICRP on every single one of the comments that we provided for them during this discussion process. We asked them on each occasion to try and provide some additional guidance which we could use that would help us in regulatory decision making and otherwise.

It is not there. Whether it could be, again, I suspect that this is probably one of those questions where if we polled the group here, there's probably 25 or 30 people in the room, you'd have N plus 2 views on what the number might be and the reason that they would pick it.

MEMBER WEINER: Let me ask you one final question. Is there a way or anything that could be

brought to the commission that would make -- that would encourage them to come up with some kind of quantitative recommendation as to the limits of the use of collective dose?

DR. COOL: Well, that's an interesting speculation. I'm not sure what circumstance might be the sufficient threshold to get them to actually try and write something like that down. I'll tell you from my personal standpoint, a much more pragmatic solution found within what they say in Publication 101, which is in the context of the decision-making, setting aside your issue of doing a complete calculation and using an number as a reference for anything.

MEMBER WEINER: Right.

DR. COOL: But in the context of decision-making, we then have the ability to look at the various attributes and to apply constraints, if you will, controls over those numbers so that the values you're calculating help you to differentiate between the options is one of the things which you're alluding to, is that if you do the complete calculation and you compare options, you see almost no difference because it's being driven by the tail end, so it's not useful in making the decision.

But if you change the way you do the calculation, calculate it for a smaller distance or different time intervals, you can get values which will help you differentiate between the options. That is an appropriate and very useful way to help make decisions.

CHAIR RYAN: Now we're back to your worker example.

DR. COOL: Exactly.

MEMBER WEINER: Yes.

CHAIR RYAN: You've got a case where A versus B is a relative comparison of two, you know, nearly equal things and I'm trying to see if there's a difference.

DR. COOL: Right, right, that is the place that they suggest is a very important and useful use of collective dose, is and can and should be used in those context to help you make those decisions.

CHAIR RYAN: And just for everybody's benefit, our letters to the Commission on this topic have said exactly that.

DR. COOL: Yeah, right.

CHAIR RYAN: Jim?

MEMBER CLARKE: Just a comment and maybe you can get into this a little more on Thursday, but

it strikes me that -- and believe me, I'm not defending by any means the use of non-human end points but it does strike me that if there are no limits associated with these end points, then the dose calculations could be used in a relative sense to evaluate say, remedial alternatives and in an ecological risk assessment. Alternative A gives this, Alternative B gives this. Alternative A costs that, and again, if you're not taking these calculations, I'll say so seriously that you're establishing limits, which would be something else, as is the case with collective dose. Maybe it's a tool that could be used to make relative judgments.

DR. COOL: I believe you're correct.

MEMBER CLARKE: And in that sense, I think it might be useful.

CHAIR RYAN: I struggle with the relative judgment because, again, without an end point, how are you going to deal with two species as lethal doses I order of magnitude or two orders of magnitude apart? It doesn't make any sense. It's not consistent.

MEMBER CLARKE: I don't know. I don't think I know enough about it to go that far.

CHAIR RYAN: Well, you know, I can tell you that flies in East Tennessee take 10,000 rad shots

and do just fine but if the temperature drops below 53 degrees, they die. That happens all the time.

MEMBER CLARKE: So, I'm not finding that particularly useful but --

CHAIR RYAN: The point is, how do you get to an end point?

MEMBER CLARKE: Yeah, well, I guess that's the calculation.

CHAIR RYAN: So you regulate temperature in that case instead of radiation.

MEMBER CLARKE: The same problem is true with chemicals where you try to do an ecological risk assessment, you don't know what end point to look at. So it's really the same problem.

CHAIR RYAN: But I think that's the analogy. It's not been possible to do it for a chemical end point.

MEMBER CLARKE: Well, people do it, you know, I question the value of it.

CHAIR RYAN: Yes, Thursday.

MEMBER CLARKE: But again, on a relative standpoint is that there could be some merits --

CHAIR RYAN: And they would be?

MEMBER CLARKE: -- for what it's worth. Well, I want to hear more from him.

CHAIR RYAN: Anybody else? Okay, with that we are a few minutes behind our appointed hour for a short break. We'll come back in 15 minutes at 2:00 o'clock and pick up from there. Thank you.

(Whereupon, a short recess was taken.)

CHAIR RYAN: Okay, can I ask everybody to take their seats. We'll reconvene, please. The next presentation is the Corrosion of Waste Package and Spent Fuel Dissolution in the Repository Environment and Dr. Weiner will be out cognizant member for this briefing. I would ask, we've had, I think, a number of folks join us at the center and other participants on the phone. So I would ask you -- at the center you said you a large number of folks. Center?

MR. AXLER: Yeah, we have about 10 people here.

CHAIR RYAN: Could I ask that instead of trying to recite your names out that you make an attendance list and fax it up here to the NRC?

MR. AXLER: Okay.

CHAIR RYAN: And apart from the center, do we have --

MR. AXLER: Okay, we'll do that.

CHAIR RYAN: And your name is?

MR. AXLER: I'm Keith Axler, the Element

Manager for Corrosion Science and Process Engineering.

CHAIR RYAN: Keith Axler, thank you very much. We'll use your name as the lead and attach the list that you fax up to the NRC office. We really appreciate you doing that. It makes our record complete and a little easier to manage.

Do we have any other participants not from the center?

MR. DIBELLA: Yeah, this is Carl Dibella at the TRB.

CHAIR RYAN: I'm sorry, Tobella?

MR. DIBELLA: Dibella.

CHAIR RYAN: Could you just get a little bit further away from your phone.

MR. DIBELLA: Yeah, Carl Dibella.

CHAIR RYAN: Dibella, okay, thank you.

MR. FITZPATRICK: Charlie Fitzpatrick, State of Nevada.

CHAIR RYAN: Anybody else? Thank you, Charlie. Anybody else other than Charlie?

MR. FRISHMAN: Steve Frishman, State of Nevada.

CHAIR RYAN: Thank you, Steve. Anybody else? All right, I thank you very much for your patience in taking the roll and I think we've got

everybody and I'd ask you to put your phones on mute so that we don't hear the bumping and so for on the microphones up here because is it quite loud. With that, I'll turn it over to you, Ruth. Thank you.

MEMBER WEINER: Thank you. And we're very gratified and pleased to have Tae Ahn once again and Sheena Whaley is also here to answer our questions and people at the Center, I leave it to between you and whoever is coordinating, if it's a question that Tae wants to have one of you answer, I'm sure he will say so.

I will say in introducing this that the committee had a number of questions about corrosion after that last presentation that Tae made and time did not permit us to get them all on the table, so we submitted a list of questions and Tae, I want to really congratulate you for the presentation because he has put it together in answer to every one of our questions. So carry on.

MR. AHN: Thank you very much, Dr. Weiner, for you nice introduction. This presentation was prepared by team member of Engineering Barrier System in Post-Closure, ENG-1, Degradation of Engineer of the Various Systems, ENG-3, Quantity and the Chemistry of Water Contacting Engineering Barrier and the Waste

Form, ENG-4, Radionuclide Leach and the Solubility Limits, Division of High Level Waste Repository, Safety with NRC and the CNWRA.

Dr. Weiner, gave us a general guide for our presentation. The first one was the most important considerations in any corrosion discussions to the committee are what radionuclides at what activity are released from the waste package and second, how are they released? Those two are our general guidances and the following questions were directed towards these two considerations. We may not present quantity release characteristic but in the end we'll present risk perspective related to all corrosion involved.

We'd like to address first to this guidance examples of releases and release mode. What is a potential release depends on physical state such as power pallet or dissolved state, something like that, and the chemistry, mainly radionuclide types of spent nuclear fuel, radionuclide. First group is rapid release of gap and the grain boundary radionuclide inventory. After reactor discharge, some radionuclides will be accumulated at the gap between cladding and the UO_2 matrix, also grain boundaries within the matrix of UO_2. Such radionuclides include

Carbon 14, Iodine 129, Cesium 135, and Technicum 99.

With the contact of water, these radionuclides will be released rapidly. Therefore, in performance estimate the release of radionuclides assumes to occur instantly. The second group of radionuclides include high solubility radionuclides such as Iodine 129 and Technicum 99. These radionuclides will dissolve in solution without any limit. Therefore, release usually will be controlled by spent nuclear fuel, U30 solution rate, that's rate limiting step, not the solubility limit.

And these radionuclides generally contribute to those in early period of time such as sometimes 10,000 year period. And the third group of radionuclide will be low solubility radionuclide inventory, such as Neptunium 237, Plutonium 239-240 and Aminesium (phonetic) 241. These radionuclides have very low solubility, therefore, release will be controlled solubility times flow rate basically solubility is concentration per unit volume. Flow rate is volume per time. Therefore, the amount of radionuclide release per time really calculated.

Not only solubility limit, sometimes these radionuclides form solid particulate in suspensions. That will increase the effective solubility limit

orders of magnitude. That is especially true for plutonium and aminesium. Therefore, this character will include solubility control to radionuclide as well as colloidal forming radionuclides.

That explains the first questions of the committee and the second, next step in assessing the release, we need to consider then what would be a potential release mode. We considered two release mode. One is bacterial release. The other one is diffusional release. They would depend on groundwater flow rate, especially through perforations of cracks of waste packets caused by corrosions. If you have high flow rate, it's direct flow release large amount of radionuclide.

On the other hand, if you have very shallow tiny cracks or small pits, the release will really depend on diffusion of the process of radionuclide in the near static solution conditions. Now, we are going to each questions. The first question was, explain, using temperature as a time surrogate and discuss the type of result the staff expect. And there was some explanations.

It was mentioned during the September briefing that one of the center's reports mentioned using temperature as a time surrogate try to reproduce

what would happen at lower temperatures over longer period of time by accelerating the process by heating. Also staff indicated that this would be discussed further during the TPA presentation but the subject matter was not mentioned. Refer to ACNW Tuesday September 18th, 2007.

I will go one by one. First, experiment and temperature to simulate the long times, what I use it for -- and I'll say corrosion and the extent you pick your studies. In other words, with the value is higher temperatures than expected repository temperatures. So you use the real expected temperatures in testing. The second one is temperature could be used as a time surrogate as rate of important chemical reactions increase, predictably with time. A good example is Arrhenius relationship. The premise of this theory is that the repository temperature decreases very slowly compared with most laboratory testing time. For instance, one-year testing or one-month's laborative testing actually repository temperature is nearly constant. Therefore, we can use isothermal conditions to derive the generic equations. Therefore, in each time interval you have one constant temperature. If you add up all those time steps, it will be time-scaled. That's why it

isn't considered as temperature -- time surrogate.

Examples of those are kinetics derived at temperature from 35 to 240 degrees C. In truth kinetics of general corrosion rate, it's a long term process of corrosion at the very low corrosion rate and also localized corrosion criteria. Depending on the temperature and the environmental chemistry, corrosion, localized corrosion could often not occur. It's all depending on temperature conditions and chemistry.

Third category is kinetics of spent nuclear dissolution. As I mentioned in earlier slide, sometimes the solution rate itself controls release of radionuclide if there is a high solubility limit. That determination was used at different temperature scale, again.

Second question was, explain how the corrosion experiment at the center has been performing since 2003 are going to be used first in the LA review and B, in the PA. Use of CNWR information is to assist the LA review and it will depend on what information is provided in LA. Then I will say more specifically how we could use our results. And independent information could be used to assist LA review. Independent information means center result

or other literature information, will be used in the area such as data and model justification, data uncertainty, model uncertainty and model support.

Topic, investigate an Alloy 22 since 2003 include a bunch of references were attached in the end. The first copy is general corrosion, center and we studied to determine general corrosion rate at different temperatures, different time scale and the stability of --

MEMBER WEINER: Excuse me, I'm going to stop you a second. Did someone else just come on the bridge line?

MALE PARTICIPANT: Yeah, my name is (inaudible).

MEMBER WEINER: Sorry, go on.

MR. AHN: Upside stability as a protective passive film and modeling and the second category is seepage groundwater crevice corrosion. When temperature comes below 110 degrees C, there will be groundwater seepage onto a Waste Package. At that time, temperature is still high. The concentration of seepage water will be further concentrated like four times, ten times. That may pose a low clad corrosion. We studied effects such as the stifling of propagation of crevice corrosion and crevice corrosion of similar

and dissimilar metal such as Alloy 22 contacted with titanium drip shield were studied.

And the third category is dust deliquescence corrosion. If temperature is higher than about 110 degrees C, we do expect the seepage with contact. However, the dust may collect water from the moist because some combinations of salt could deliquescence even at high temperature of up to 200 degrees C. Therefore, we studied whether such deliquescence corrosion could occur under such combined salt conditions. What kind of corrosion could occur were studied.

And stress corrosion cracking, mainly we did more modeling based on previous data tested on the various environmental conditions and temperatures. Also stain rate was another factor to be considered and based on the groundwater chemistry consideration, some important risk information was given. I will go over that later.

And microbially influenced corrosion was continued by literature search. Even though we can get some information from short-term testing, it is very difficult to apply electrochemical technique in predicting low crevice corrosion in this microbially influenced corrosion because microbial reaction can

not be detected by electrochemical process. So we did some long-term testing there.

And the last is the effects of fabrication process. In fabricating the waste it always create a defect the way structure, etc. We studied how those structure affect all these corrosion models.

And the number three question was what results have been obtained from studies of passivation and how do they apply to corrosion studies on the waste package. Our responses should discuss the experimental work shown with respect to formation and the stability of passive film and the sources sulfur in the repository that would enhance chemical breakdown of passive film. Note that the passive oxide film can be altered that may produce localized destruction over the film. So question three is application of waste package and the passivation studies.

The first study was passive film persistency. It is generally known chromium-rich oxide protects the metal surface. Corrosion occurs by this equilibrium between the metal and the solutions. So it never had been in equilibrium with the solutions. Always the driving force there. It continues to dissolve.

However, if you form oxide, in other words, dissolved metal reaches solubility limit, it will precipitate. That's a passive film. That's the -- The reaction never stops. It dissolves, form, passive film. It's the equilibrium process. Therefore, to keep the passive film thin, about five nanometers, is important. Oxide is surface dissolved. Therefore, we keep a nearly constant oxide thickness.

It is very difficult to predict the stability, persistence of passive film in such a long period of time. Therefore, we attempted two areas. One is thermodynamic analysis, in other words, equilibrium study to assess the long-term stability. The other one is analog consideration such as Josephinite where iron and a silica oxide film was observed very, very long time, 100,000 years. Meteorite and nickel passive film was observed such a long time. Also there are a lot of data in the reactor operation, especially steam generator materials. It's basically very close to Alloy 22, Alloy 825, etc. Also it's higher temperatures. It's more useful where we don't have much database. So we put together all this information and put out as a product document.

And the second, more specific issue in

passive film persistence is the anodic sulfur segregation. When the metal dissolves and oxide forms, most metals dissolves. Chromium will form. Oxide still dissolves. But somehow sulfur which is not metal will stay there, remain at interface or on the surface of the metal. It may at some point of time destabilize the passive film. Unfortunately from theoretical calculation such condition could occur like over 100 years. So we cannot test it in the lab.

Therefore, we need to assimilate that. How do we assimilate it? Two different ways you could assimilate. One is you combat with sulfur to implant the sulfur at interface to the amount you can expect at 100 years. That's one thing you could do. It's very difficult for there are a lot of artifacts could be involved. Therefore, the central choice is the electrochemical method. As the scratched metal was exposed in sulfur containing solution like thiosulfate or sulfide solution, Marcus of France has demonstrated both effect the ion implantation as well as solution containing testing have equivalent effect. There are a number of papers on that. So we used that condition.

And, in fact, sulfur impurity may be right now up to 100 ppm in the current available alloy. But

a detrimental effect of sulfur segregation can be reduced by reduction of initial sulfur content in alloy like 1 ppm using a variety of different processing techniques.

And the last one is the question of alpha effect. In fact, this was a fact excluded some time ago. So Dr. Weiner reminded us to revisit that, review it again. We did that and recognized that the effect of passivity appeared limited. That's the answer to your question.

The reason is the following. No significant source of alpha particles to contact the passive film. Alpha particles inside the Waste Package cannot penetrate through the Waste Package under nomianl conditions and there is no other significant source of external alpha particles.

The only possible alpha particle source is from early-failed adjacent Waste Package. In other words, when you have early Waste Package and something coming out there, that could mitigate to the waste impact and Waste Package. That's the only one you could consider. It's very unlikely geometrically. It could fall down. It will not go out. Also very small amount like radon is the only gaseous one. It can go out. But all radons are inside metrics. So really

coming out is --

Nevertheless, limited analysis currently are being performed to support review of DOE's FEP exclusions.

Now the number four question, it's pretty long. Why do studies continue on dust deliquescence especially since there is no impact? Also is the staff making some assumptions that water would actually be more likely in contact with the Waste Package than with dust? Further, discuss the experimental evidence that crevice corrosion by dust deliquescence does not affect the Waste Package performance.

There is a question. The stifling of crevice corrosion is once you consider the relevance of the statement, note that current information from Center experiment indicates that crevice corrosion by dust deliquescence does not affect a Waste Package performance significantly. Staff's response in September was not clear. Transcript from the meeting state that. Actually, that's a good point. The deliquescence will continue to this area. However, the corrosion failure is from seepage water. That's why we made this distinction. We'll go and continue here. It will be terminated by seepage water. You

could assume several different assumptions of holding of water either dust or on the metal.

Now I will go on by basis for dust deliquescence corrosion. It's very unlikely. Nevertheless, staff needs to review basis for potentially included as well as excluded Features, Events and Processes. This could be excluded FEPs for study. That's your answer.

The second one is Alloy 22 corrosion testing in salt brines (potentially composition of dust deliquescence brines) shows that general corrosion could occur, actually testing, not theory, not modeling. It's actually testing with the combination of three salts, sodium chloride, sodium nitrate and potassium nitrate. That gives the deliquescence at highest temperatures.

Also we can study the models for cathodic capacity. In other words, if you have a limited amount of water outside the crevice with dust deposit, that may not give sufficient throwing power to induce the corrosion. Therefore, we studies how much water is needed. Actually, we saw there was some limited capacity of a cathode to limit the corrosion inside the crevice on the dust deliquescence conditions.

So both experimental modeling support,

it's very unlikely, low crevice corrosion is very unlikely. However, we do observe the general corrosion.

During the potential brine period, dust will be present. Although corrosion by seepage groundwater may dominate, dust deliquescence effects on general corrosion contribute to variability and uncertainty in PA. So we consider this deliquescence period here in brine period, too. It will be continued as I indicated in my previous presentation.

(Off the record comments.)

MR. AHN: Next two questions, it's related to water flow and the dust again. I will read again. Question five is what is the role of brine. What rate of water flow would be needed to get to the brine period.

NRC has done a great deal of work in the formation of humidity, deliquescence and the corrosion induced by deliquescence on the Waste Package surface. The graph below shows to regions of potential corrosion, dust deliquescence and the brine period. However, a concentrated solution deliquescence on the surface will have high surface tension and thus the only minimal contact with the surface while the dilute solution that can spread over the surface will be

minimally corrosive. It would appear that there would be little corrosion during either period. Defend the statement made by staff at the September meeting, "Dust may form brines for deliquescence at elevated temperature and some deliquescence brine can induce general or crevice corrosion." Note that concentrated brine has high surface tension and stick to the dust.

And I'll go one by one. Corrosion during dust deliquescent brine period, in the dust deliquescent corrosion period, capillary retention of dust deliquescence brines by rock may reduce the amount of water that contacts a metal surface but does not prevent corrosion from occurring though. That's what we observed from tests.

In the brine period, temperatures appear high enough to form concentrated brines. Usually to initiate low crevice corrosion, you would have some kind of a concentrated brine from seepage water, at least, four times concentration. In addition, you need to have high temperature, crevices, etc. So it's not generally stated that what concentration could cause a low crevice corrosion. However, very low seepage case, you cannot form the sufficient amount to cause like four times C-13 well water concentrations. That's a distinction between dust deliquescence period

and seepage groundwater period.

I will repeat once more. This is time period of one million year temperature and the relative humidity. We have a dry period here. It's only dust that can absorb water and after that you really will have seepage groundwater about several thousand years later and the temperature will go down continuously.

And the next question is stress corrosion cracking. Question seven is what, if any, is the role of stress corrosion cracking. How does experimental work support this? The initiation of stress corrosion cracking of Alloy 22 has been observed only in past using either cyclic loading or constant straining with high applied potentials. Low stress corrosion cracking of Alloy 22 has been observed for constant deflection conditions in simulated groundwater on anodic and alkaline conditions. DOE indicated that drip shield would be in place in stress mediated conditions.

And Question number seven is about role of stress corrosion cracking. Stress corrosion cracking could have an effect by allowing a limited amount of water into tight cracks in the Waste Package, not like general corrosion. It's more like cracks. Very

limited water can get into Waste Package and the radionuclides will get out in a very limited manner.

Formation of stress corrosion cracks requires basically carbonate and bicarbonate solution. That's why we only observe it at high potentials. However, such concentration are not expected in the repository. Therefore, the Center analysis support that SCC is an unlikely process under potential repository conditions.

Nevertheless, our TPA considered uncertainties associated with SCC model abstractions. So that's the current status.

Question eight is explained by what chemical mechanism is the Waste Package destroyed. How is this mechanism initiated? What conditions are required to be maintained for this mechanism to function? What is the degradation for rate for this mechanism?

Initially, we wrote trying to answer all these sub-questions, but recognized it's not necessary. So we summarized. To destroy meant to us to have large opening of Waste Package. So it's separated general corrosion from the rest of the model corrosion. The rest of the model corrosion generally produced tight crack or a tiny pit. So it really

doesn't open the surface. On the other end, general corrosion could open a larger surface area.

Compared with the other failure model of the Waste Package, mechanical or any type, corrosion mode is the likely process to penetrate through the Waste Package and the general corrosion likely will occur over a very long period of time because general corrosion rates are very low.

General corrosion may eventually create large enough opening in Waste Package to support advective release. It will be a sufficient amount of radionuclide.

How does it happen? It basically happens by the loss of passivity. That's why we studied persistence of passivity loss for enhanced general corrosion. In other words, when you expose the metal The solution rate will occur mainly higher. So impurity segregation such as sulfur is a good example to destabilize the passive films and there are other issues. NTTIG collected that information years ago, corrosion product accumulation, to induce larger surface area of cathode or to alter the chemistry adjacent to metals or you thicken the oxide film, you could generate the stress there too. They can spall off the film.

However, current notion is outside the layer is continuously dissolving and inside the layer is continuously generating. They are probably the constant thickness could be capped. Even if generated, it becomes part of the outside and will not contribute to the real corrosion rate. And basically, long-term dissolution nor repassivation is the cause of the opening at the surface area in a shorter period of time.

And question nine is what are the sources of nitrate in the repository. Explain how this has been confirmed. EPRI studies appear to show that nitrate solution inhibits localized corrosion.

There are two likely sources of nitrates in the potential repository. Atmospheric aerosols could be entrained in ventilation air and deposited together with dust particles on the waste package surface during the preclosure period. The soluble fraction of atmospheric aerosols over continental landmasses typically is dominated by nitrate, sulfate, ammonium and sodium. Nitrate concentrations in leachates of dust samples taken by the U.S. Geological Survey from the Exploratory Studies Facility at Yucca Mountain range from several tens to about 1800 ppm.

Now the second source is nitrate dissolved

in groundwater. Nitrate concentrations reported by the USGS for porewaters extracted from rock samples taken from the unsaturated zone of Yucca Mountain and the vicinity typically are in tens of ppm. Although these porewaters are initially dilute, evaporation may increase or decrease the concentrations of dissolved constituents, including nitrate salts.

EPRI's studies appear to show the nitrate solution inhibited by localized corrosion. Actually, Center produced a similar behavior, similar effect of nitrate on corrosion. This is the Y axis is the repassivation potential. When corrosion potential exceeds repassivation potential, localized corrosion, crevice corrosion. Below that, localized corrosion will not occur.

Now the higher the repassivation potential, less susceptible to localized corrosion. X axis is nitrate to chloride ratio. Nitrate is an inhibitor to localized corrosion. Chloride is a promoter of the localized corrosion. So if this ratio is higher, the less susceptibility to the localized corrosion. As you see here, if you increase the ration, the repassivation potential increases respectively from 0.1 to almost -- Corrosion potential never reaches -- Therefore, localized corrosion would

not occur.

This test was done Alloy 22 4 M Magnesium Chloride solution, very concentrated solution at 80 degrees C and 110 degrees C. It's conforming the EPRI's postulate.

And Question ten is now we're moving from corrosion to spent fuel. Compare dissolution rates for low burn-up and high burn-up fuel. Dissolution studies need to get data on high burn-up fuel characteristics, excess hydride, oxide fission product and oxidation of high burn-up fuels.

The first question, available information indicates that high burn-up spend fuel does not increase the dissolution rate. Here you can see in this rate milligram per cubic centimeter per day versus burn-up up to 70 gigawatt day per metric ton unit actually decreased here. This data is a corroboration. It's a collective data and laid out in one chart by Jain of the Center. You can see it's decreased up to 70.

However, there are other factors we need to consider in determining actual release. Some physical steps could be changed, for instances, prior dry oxidation from UO_2 to U-2308 could increase the surface area substantially. That consequently

releases more radionuclide because this rate is a pore unit surface area.

Second concern is hydride formation. That could again not affect the dissolution rate itself but potentially alter the surface area of the fuels. So those too are a physical conditions, however, the dissolution rate did not change.

The next question 11 is explain why the results from the testing of SIMFUEL accepted the two steps. SIMFUEL is a nonradioactive UO_2-based fuel containing simulated fission product such as barium, etc., to use in laboratory. The Center still bases its conclusion on experiments done with simulated fuel with a stable isotope important fission product like cesium. Simulated fuel behavior differs from SIMFUEL primarily because it's opens and are not bound to the uranium oxide in the same way that fission products are bound. Moreover, the radiation damage done by emission from oxidized spent fuel is not duplicated in simulated fuel.

First, I would like to clarify after we proposed this committee center only did modeling literature analysis actually did not test any SIMFUEL. The second one is the opened, you could have two characteristics. One is the chemistry changes. The

other one is radiation effect.

As I see in the first bullet, dissolution rates of spent fuel, unirradiated UO_2 and SIMFUEL are undistinguishable in terms of the chemistry bound not only formed as long asa the environmental conditions are very similar and the database listed --

CHAIR RYAN: Excuse me. Somebody doesn't haven't their phone on mute and every time you move it's creating a lot of noise. If you could all check your phones to be on mute, we would appreciate it.

MR. AHN: NRC recently put out a report here and the French have very expansive report. Canadian, Spanish, these are all review reports. They concluded the first --

MEMBER WEINER: Did someone else just sign on to the bridge line?

CHAIR RYAN: Sorry. Go ahead.

CHAIR RYAN: He hung up. Somebody hung up.

MEMBER WEINER: Hung up. Okay.

MR. AHN: There were no distinction between those three fuels testing. And radiolysis, however, effects on spent fuel dissolution may be significant in reducing environments like in the Swedish or German, Japanese. The potential Yucca

Mountain repository is oxidative, not reducing, with abundant buffered oxygen available. Therefore, radiolysis is anticipated to have a negligible effect on an oxidized system. That's our observation and analysis result.

However, there are some uncertainties regarding the geometry of alpha particle emission as you indicated after potential container failure. For instances, all laboratory testing was done where it defined amount of fuel, water, but in actual repository you have bundles there. There could be some geometric effect there. Most of those overlapping radiation shield each other. There is none basically, but still we want to be sure.

Question 12 is how long irradiated fuel behavior on the repository conditions and over a long period of time. How stable is the cladding? What is the physical degradation rate of irradiated fuel in intact Waste Package? What is the role of hydride in fuel degradation? Should it be considered that the Waste Package has undergone some corrosion and high burn-up fuel effect?

I go one by one actually. Long-term physical stability of irradiated UO2 matrix, other than chemical degradation, in other words,

dissolution, ongoing work in Europe especially the European Commission, Karlsruhe Laboratory, ITU, indicates that long-term stability of crystal structure/integrity and stable radionuclide distributions. They didn't see any significant alteration at varying rates simulating a long period of time.

Another physical degradation could come from -- Physical degradation basically coming from alpha displacement damage as you indicated. There are other mechanisms such as mechanical failure, sometimes assisted by chemical process such as hydration. For instance, UO_2 could hydrate, just absorbing moisture from environment. They could hydrate without dissolution and become rapidly dissolved later with water comes in. And hydrogen embrittlement in cladding, you probably heard a lot from the SFST on this issue.

And now moving to stability of cladding, cladding could be subjected to either gross rupture, you know, completely open up UO_2 or it just forms perforations like small holes or tight cracks by applied -- it's basically coming from given stress and temperature needed. So these kinds of stability is coming from, determined by applied stress, hydrogen

embrittlement or corrosion through time.

What is hydriding? Hydriding means the zirconium could react with hydrogen in the cladding to form zirconium-hydrogen hydride. That's very brittle. Therefore, the mechanical -- this integration could occur at much lower stress levels than normal yielded stress or tensive stress. That's called hydrogen embrittlement or if you have very small inside of the crack, if hydriding occur, that could populate very rapidly.

You normally after -- that could discharge. The hydride is lying circumferentially. Therefore, any hoop stress would not affect the mechanical property. However, you have a temperature or stress of uncertain level during the repository performance, those circumferential hydride reorient to other radially. Therefore, any hoop stress can cause a crack propagation. That's the mechanism. The radial hydride also could form by absorption at crack. That's another stress because cracked you have usually very stress levels. Those answer your four questions.

The last one is risk -- It's really tied to the very first slide about radionuclide release for all these processes. Provide risk insight regarding how and any new thinking on corrosion influence the

release of radioactive material from Waste Package over time with the availability of transport into the nuclear environment.

The fundamental risk insights, we prepared in 2004, have not substantially changed in light of new information and radionuclide release depends in part on the extent of surface-area opening. I emphasized a few times in the past slides. Small surface area opening for groundwater entry into the failed Waste Package or limited groundwater volume restricts the mobilization of radionuclides inside Waste Packages. Those two are a sense of the risk determinations, risk assessment.

The expected extent of surface area-area opening for various corrosion modes includes general corrosion. Loss of passivity gives relatively large opening and may lead to advective release. On the other hand, crevice corrosion making a restricted opening from susceptible water chemistry, tight crevice area of buckled drip shield and Waste Package and weld area. If you put it altogether, the restricted area could open, may lead to only diffusional or in some cases, you may have limited advective release, too. SCCs, first of all, are unlikely. But even if it happens, a very restricted

tight cracks and they may lead to only diffusional release. New internals of Waste Package in tight canister will reduce the colloidal release because carbon steel is no longer used.

Now those are our risk insights I present. I think during answering these questions I answered your second questions, all of them. Okay.

Now one more thing I didn't address. The stifling of crevice corrosion on the deliquescence corrosion, we did not consider it because localized corrosion did not occur in our observations. That's all I have.

MEMBER WEINER: Thank you very much for a really very thorough presentation and I'm going to start the questioning off with Dr. Clarke.

MEMBER CLARKE: Thanks, Ruth. Let's just leave that slide on. Your first bullet, fundamental risk insights have not substantially changed in light of new information, I guess the new information or the studies you've done since the risk insights. At one time I think we may have recommended that during the TPA discussion that risk insights, in fact, be revisited. When you make that statement, is that a result of actually going back and looking at risk insights, picking what you're learned and redoing --

MR. AHN: Yes.

MEMBER CLARKE: if you will, the risk insights? In other words, this is stronger than just kind of a feeling you have. This is the result of an evaluation, that statement.

MR. AHN: Do you have any comment?

MR. McCARTIN: It's based on the -- obviously knowing what we had written before and analyses we have done with the TPA code and looking at the results. That's not to say we continue to do analysis with the TPA code, but certainly in terms of the results we're seeing it's consistent.

MEMBER CLARKE: Okay. And we've had earlier presentations as you know about drift degradation and we talked about that earlier today among ourselves, I guess, in a letter writing. You're looking at various corrosion mechanisms. I guess, Tim, I'll ask you the same thing. Are these being looked together at any point?

MR. AHN: Yes. I actually addressed, too. Corrosion occurs because metal and solutions. It's spontaneous reaction. You cannot stop it. However, when metal arrives at the solubility limit, it reprecipitate as an oxide. That's a passive film.

That alternation process continues. It doesn't stop.

MEMBER CLARKE: I'm talking more about rock fall damage, rock fall physical damage.

MR. AHN: Yes, rock fall could damage on the seismic conditions the Waste Package. On the other hand, the rock fall could push the Waste Package, drip shield, onto Waste Packages and there form crevice.

MEMBER CLARKE: Right.

MR. AHN: And under crevice conditions, you really lose the passive film because of the occluded area where pH is low. There is no oxygen. You completely dissolve oxide protective layer. Therefore, the propagation of the metal is very fast.

MEMBER CLARKE: I understand. The question is that you are looking at this and the performance assessment together.

MR. AHN: Yes.

MR. McCARTIN: Right, but if you're reading that first bullet in which says "fundamental risk insights have not substantially changed in light of new information," that statement isn't being made in a global sense for everything.

MEMBER CLARKE: No, I understand.

MR. McCARTIN: I mean it's relative to the

things below it, the same kind of things we're seeing, and when we're doing our analyses we certainly are looking at a spread of things that include rock fall. But that's why I said this is true to the analyses we've done to date. That's not to say we've done all the things we're going to do and don't have further things to learn. But for in this narrow area of corrosion, this is.

MEMBER CLARKE: That was the way I interpreted the sentence. The second question was really a different questions. Okay. I think we're a little pressed for time. I'll stop here.

Thanks, Ruth.

MEMBER WEINER: Mike.

CHAIR RYAN: No, I'm fine. You go ahead.

MEMBER WEINER: Allen.

VICE CHAIR CROFF: Thanks.

Early in the presentation you mentioned rapid release of gap and grain boundary radionuclide inventory which I understand up to a point at least. It seems to me at some point after you start to penetrate in the grain, doesn't the rate slow down and it become limited by diffusion and matrix dissolution because the water doesn't have, or the ground doesn't have access.

MR. AHN: Yes. There was a conservatism involved in the actual performance assessment. In actual chemical phenomena, yes, it could be diffusional release. There would be some time to release completely the grain boundary in there. However, the time scale of that release would be much shorter than the repository time period. Therefore, it would not be included in TPA model as a function of time. It just happens.

VICE CHAIR CROFF: Okay. And is the result of grain boundary, release at grain boundary, does that disintegrate the fuel pellet?

MR. AHN: If there is a -- There was actually data observed of about 25 grains penetrated normally. So maybe less than one-tenth, it's not much. But in actual release from metrics, it wouldn't matter whether grain boundaries are partially penetrated or not because the secondary phase masks the whole surface. The actual contributing surface is geometric surface. The other is of grain boundary penetration. To some extent, yes, but not substantially, people studied that. Yes.

VICE CHAIR CROFF: Okay. I'm on slide four but one of your bullets mentioned temperature being used as a time surrogate. Doesn't that use

assume that the mechanisms of degradation or corrosion don't change?

MR. AHN: It will change. However, we use the temperature range expected in the repository. We test from like 25 degrees C all the way to 205 degrees C. Even that kinds of changes we capture that.

VICE CHAIR CROFF: Okay. You talked about sulfur and how it enhances corrosion. I was a little bit unclear. Is the source of the sulfur in the metal or is it in the groundwater?

MR. AHN: In the metal.

VICE CHAIR CROFF: It is in the metal.

MR. AHN: Yes, in the metal. I'm sorry.

VICE CHAIR CROFF: Okay. So I'm not quite sure. How is testing with external solutions of sulfides and thiosulfates relevant? Is there a presumption -- Well, how is that relevant?

MR. AHN: There are a number of theories mostly developed by Marcus in France. What he's saying was they do a lot of a studies. Actually, still we do them. No, it's only theory. It is sulfur could be accumulated at the interface of metal and oxide. But in reality, we cannot detect that. If you probe with an analytical tool, you cannot probe the interface alone. Usually it's a bigger area.

So the more possible thing is sulfur could be embedded even in passive film, too. That could answer why you could simulate with solutions because when you have solution, especially when you scratch it, you expose purely metal sulfates. Then instantly sulfur could be absorbed on the bare metal surface, the inner passivate. Therefore, sulfur could be implanted much deeper even from the solutions. But that's one region.

VICE CHAIR CROFF: Okay, but all the sulfur driven corrosion is theory.

MR. AHN: We extracted it. Yes, but we extracted it. For instances, we scratched the sulfur containing solution. We took our sample in solution without sulfur and see the behavior. Yes, we have separate techniques to extract the continuous solution effect from the real metal surface effect.

VICE CHAIR CROFF: And you have observed accelerated corrosion?

MR. AHN: Yes.

VICE CHAIR CROFF: Okay.

MR. AHN: It's about not significant --

VICE CHAIR CROFF: On the nitrates, I'm looking at your graphic, the graph that shows the change in potential, and if I'm reading this right, up

near 600 millivolts I'm seeing a scatter of symbols, some of which indicate no crevice corrosion and some say there is crevice corrosion at the same point. How can you draw any conclusion from this?

MR. AHN: Yes, crevice corrosion is the black one. No crevice corrosion is the white one. It's different temperature. This is one example. General trend you have more crevice corrosion in the lower end side. That's what I have seen. That's why we draw this line here, this trend.

VICE CHAIR CROFF: Granted there is more lower --

MR. AHN: It's a trend, yes.

VICE CHAIR CROFF: It doesn't look to be a very powerful trend, is it?

MR. AHN: There are better figures, better data. I'm sorry. I should have taken that, but I thought this was direct comparison. So I took it. But there was general -- The trend is more crevice corrosion. I think there are better. But general trend is in this straight lines here.

VICE CHAIR CROFF: Okay. Finally, on the radiolysis effects in looking at the view graph, I see a lot of data supporting that the dissolution rate of spent fuel and SIMFUEL is about the same. But on the

next bullet, the radiolysis effects, is it known that there is no effect of radiolysis in an oxidizing system or is this --

MR. AHN: Yes. I give you one -- That's why last bullet I said uncertainties. One case they observed in oxidized solution they added strong radiation. Then what happened is H_2O_2 formed was not unstable. It was stable there and it really accelerated.

Such a condition could occur. The French did the testing using the various strong alpha radiation in oxygenated solution and so increased the solution rate. They varied the alpha radiation field because in the actual bundle of fuels, all alphas are shielded. It doesn't linearly add it together. So the strong radiation they used was just adding up all those alpha radiation from single rods linearly. That's not realistic at all. So there was one case, yes, we had.

VICE CHAIR CROFF: A couple of questions on the conditions. Have they looked at the effects of beta and gamma radiation or neutrons?

MR. AHN: Yes, they all come together. Alpha and gamma is more similar. Beta is less pronounced. All data coming together, yes.

VICE CHAIR CROFF: And the solutions they've used here have the other miscellaneous chemicals in them than the groundwater would?

MR. AHN: Yes, it's most groundwater containing a carbonate, chloride. Carbonate is a key issue in the water and silica and some other contaminants, yes.

VICE CHAIR CROFF: Okay. Thanks.

MEMBER WEINER: Bill?

MEMBER HINZE: Just a very few questions of a general nature. Your presentation is excellent. You also -- One of the things you come away with from your discussion is there are uncertainties in the corrosion of the Waste Packages in the dissolution of the spent nuclear fuel over time. If number one was very low uncertainty and number ten was high uncertainty, how would you expect the uncertainty in your knowledge of this dissolution and corrosion to change? How would you expect the uncertainty to change from the closure of the repository to a million years?

MR. AHN: We use --

MEMBER HINZE: And my next question, of course, as you think about the answer to that is why.

MR. AHN: That's why we use analog such as

passivity. I'm not sure it would really change much based on that observation of analog materials. The notion we have since they're applied to analog materials, too, it really depends on environmental conditions rather than materials.

MEMBER HINZE: Are you talking particularly about meteorites?

MR. AHN: Josephinite force.

MEMBER HINZE: I'm sorry.

MR. AHN: Josephinite and the meteorites. Those are examples. Passivity, it's different passive film like oxide silica or oxide. It's still there. That's what we are talking to.

Tim?

MR. McCARTIN: I guess one way to answer Dr. Hinze's question is also in terms of temperature and the uncertainty, certainly if you go out over the million years, there's a big difference in the temperatures you see and I guess that might be one possible way. How does the uncertainty vary with time, but really because of the temperature and I don't know.

MR. AHN: Yes. That reduces the uncertainty, too. It's dust deliquescence, local corrosion, all those things. That's why I'm saying

more passivity issue in the longer period. That's the only remaining issues because solutions are --

MEMBER HINZE: Are you saying -- Excuse me, but are you saying the uncertainty is higher during the thermal maximum period?

MR. AHN: Yes. It's --

MEMBER HINZE: Let me ask. I don't want to dwell on this. Let me ask a related question. The EPA draft standard suggests that infiltration at the repository level be used as a surrogate for the climate change. That's simplification of a complex process, but basically a change in the infiltration at the repository. In your analyses, have you considered changes in surface conditions which may also be affected by the climate change, for example, the development of organic material at the surface causing complexing, causing microbial activity to be accelerated which may lead then to conditions not only of a change in increase in the infiltration at the repository level but a change in the chemical and biological activity within the infiltrating water and also the possibility that we may have a ashfall, not necessarily a volcano in the exact vicinity of Yucca Mountain, but we may have it in the region leading to an ashfall and the effect of the ashfall changes the

surface conditions and the solutes that are available?

MR. AHN: Actually, we studied even before the effect of organics like oxide acid and the effects on corrosion. Exact assessment, a more accurate assessment, based on environmental conditions were not done. However, we have some database at different oxidic conditions, what effect could occur and the corrosion performance, yes.

MEMBER HINZE: So your range of --

MR. AHN: Yes, the range of conditions.

MEMBER HINZE: The range of distribution incorporates these kinds of -- like enhanced microbial activity, etc.

MR. AHN: Yes. Exactly.

MEMBER HINZE: Thank you very much.

MEMBER WEINER: Jim, you had further questions.

MEMBER CLARKE: No. Thanks.

MEMBER WEINER: I have just a general question and most of our questions really you have addressed them and addressed them very thoroughly. Since a great many of the mechanisms that you've studied really have minor to no influence on corrosion, in other words, you have to have cracks in order to initiate the corrosion, you have to do all

those things, what is the primary mechanism by which the Waste Packages would corrode enough to release spent fuel elements into the groundwater if that happens or is this a combination of mechanisms? Does it change over time?

MR. AHN: I said, I presented, a few times. It's general corrosion. That's the most risk significant corrosion mode because it could open up the area and really penetrate through opening up to release radionuclide in the walls.

MEMBER WEINER: And the rate, you would assume that the rate of general corrosion would be enough to penetrate all of the -- Are you going to corrode all of the Waste Packages? Some of them? Over what period of time would that corrosion penetrate the Waste Package and then the TAD, assuming you have a TAD which we are assuming and then the cladding because you have to get through all those to get to the spent fuel and then dissolve -- Well, then you would release what it would be in the gap I would assume.

MR. AHN: Right.

MEMBER WEINER: And are you also assuming dissolution of the uranium dioxide matrix?

MR. AHN: In terms of corrosion of Waste

Package, it would last based on current general corrosion rate, hundreds of thousands of years. It's a long period of time unless you have some other mechanisms such rock fall or seismic effect. That may cause less restricted small openings, whereas general corrosion would occur in very long periods of time and dissolution would take another -- it's shorter than the Waste Package lifetime.

But right now, we have not seen -- We don't know whether the cladding is a credit, too, or not. Sometimes like TAD canister or there is a inner Waste Package that are not still not credited actually in the release calculations. We are assuming that there is none.

And the cladding, too, right now we don't know whether cladding is credited or not. And, however, there is one exception though initially failed the container, less than one container that is opened up from the beginning.

MEMBER WEINER: Actually, this question might be addressed to Tim. Do you have any realizations where you assume different rates, different amounts, of corrosion? In different rates, do you include? Do you routinely take no credit for inner canisters and so on?

MR. McCARTIN: In our current approach as Tae indicated, the general corrosion appears to be the process for very long term and that can open up holes of some size. The corrosion rate is varied. The extent of the openings and how much water they let in can be varied in the code. The same is true for the Department. It obviously is not one corrosion rate, but it's a range and how much water. I mean all of that stochastically varied.

But in general -- And I think from our viewpoint it's I think regardless of what we have in our code which is what we're using to help us assist our review, I think the important thing that we've learned through a lot of the tests that Tae and people at the center have done is that general corrosion appears to be a process that needs to be considered. I don't think we have any firm belief whether it's going to end up with a lot of packages failing early, or I shouldn't say early, but in the hundred thousands of years or is it in the million years? That we're not saying. I think what we're saying is that it's a process that needs to be considered and certainly you're right. There's a lot of variability in how that might end up.

MEMBER WEINER: I have one final question.

Since the question has been brought up twice today that rock fall damaging the drip shield could crush the drip shield to the point where it damages the waste -- where there would be an impact on the Waste Package, what if you didn't have a drip shield? Could you reduce the probability of that damage? Is that a scenario to consider?

MR. AHN: Actually, DOE changed the design a few times by enforcing the drip shield using the structural titanium 29. Originally it used only seven. It's more ductile. Then they reinforced it with 29. The design changed a few times to answer your question.

MEMBER WEINER: Any of the staff have -- Chris.

MR. BROWN: Chris Brown from the Staff. Tae, would you tell me if the staff plans on producing any new regs on these two subjects? If so, when?

MR. AHN: When the spend fuel dissolution report is out in ADAMS. It's not printed in NUREG or any form of report or paper but just NRC report in ADAMS you can get it.

MEMBER WEINER: Other questions? Latif.

MR. HAMDAN: Yes. Tae, do you have a process model for corrosion --

MR. AHN: Yes.

MR. HAMDAN: -- that's separate from TPA? Right?

MR. AHN: Well, it's abstracted. Yes.

MR. HAMDAN: I understand. So can you give us because some of us either do not know how many variables do you have in that model?

MR. AHN: What do you mean? In corrosion?

MR. HAMDAN: Yes.

MR. AHN: It's --

MR. HAMDAN: Roughly. I mean I'm just curious.

MR. AHN: How many parameters?

MR. HAMDAN: Variables. Yes, how many input parameters or entries do you have?

MR. AHN: At least, 30 to 50 and even higher.

MR. HAMDAN: Okay. These 30/50 parameters, what are the sources of these data that was used as input data whether these now or over time? You know, you have this by the Center. You have -- Where did you get your information about your input data from?

MR. AHN: From testing. It's like a repassivation. This is in the code. When we

calculate the corrosion separately and we give this repassivation potential at the given temperature, at the given chemistry, that's from environmental conditions at a given time.

MR. HAMDAN: Right. But --

MR. AHN: Then you compare that there.

MR. HAMDAN: Okay, but where did you get the data for this location, for this time. You see the humidity is this much or the temperature is this much. Where did you get that?

MR. AHN: That's from USI and another ISI.

MR. HAMDAN: Okay. So this seems to be at this box --

MR. HILL: Britt Hill, NRC staff. The source of the data that we're using in the TPA Code is documented in the TPA Users Guide. So every one of the parameters, the data source for that information is well documented. It's difficult to give a single source, but it's very easy to say we've considered a broad range of information that's available from the open literature, experiments that we've sponsored at the CNWRA, in addition to work that the Department of Energy has done.

MR. HAMDAN: And that was, I know something about the TPA, but that goes also to the

corrosion process model as well.

MR. HILL: In terms of the general understanding that our staff will use to review the Department's License Application, we are considering a very broad range of available information. We're going to be relying primarily on the information that the Department presents in its License Application. But we will be considering information from all other relevant sources including work that's been conducted at Center and work that's in the open literature.

MR. HAMDAN: I understand that, but you are running a process model right now with --

CHAIR RYAN: Latif, I'm sorry. I don't understand your question. Is this something that you can discuss offline?

MR. HAMDAN: Yes.

MEMBER WEINER: Yes.

CHAIR RYAN: All right.

MEMBER WEINER: I think we can close this up and thank you again very much and I wanted to thank the people at the Center for their support and I'll turn it back over to the Chair.

CHAIR RYAN: Thanks. We're a little bit ahead of time and I'm glad we've finished the subject, Tae. Thank you so much for your time and all your

preparation. We know you worked hard to answer our questions which were many. So thank you very much and thank you to everybody else that helped with today's briefing. It's been very informative.

With that, why don't we take a very short ten minute break and then we'll get back to Professor Hinze's letter and we'll go from there. Thanks. Off the record.

(Off the record.)

CERTIFICATE

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

Name of Proceeding: Advisory Committee on Nuclear Waste & Materials 186th Meeting

Docket Number: n/a

Location: Rockville, MD

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

Charles Morrison
Official Reporter
Neal R. Gross & Co., Inc.


A&M
February 12, 2008
Donald A. Cool
Safety and International Larson
Material and Environmental Management Programs
U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Publication

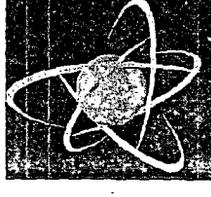
- ICRP Publication 103 was made available to NRC staff on December 18, 2007.
- Report is 332 pages in length, including appendices.

Table of Contents

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

Main Features

- Updated radiation and tissue weighting factors.
- Maintained the three fundamental principles.
- Evolved to situation-based approach.
- Maintained individual dose limits for planned exposure situations.
- Reinforced optimization with emphasis on constraints.
- Detailed approach for developing a framework for protection of the environment.



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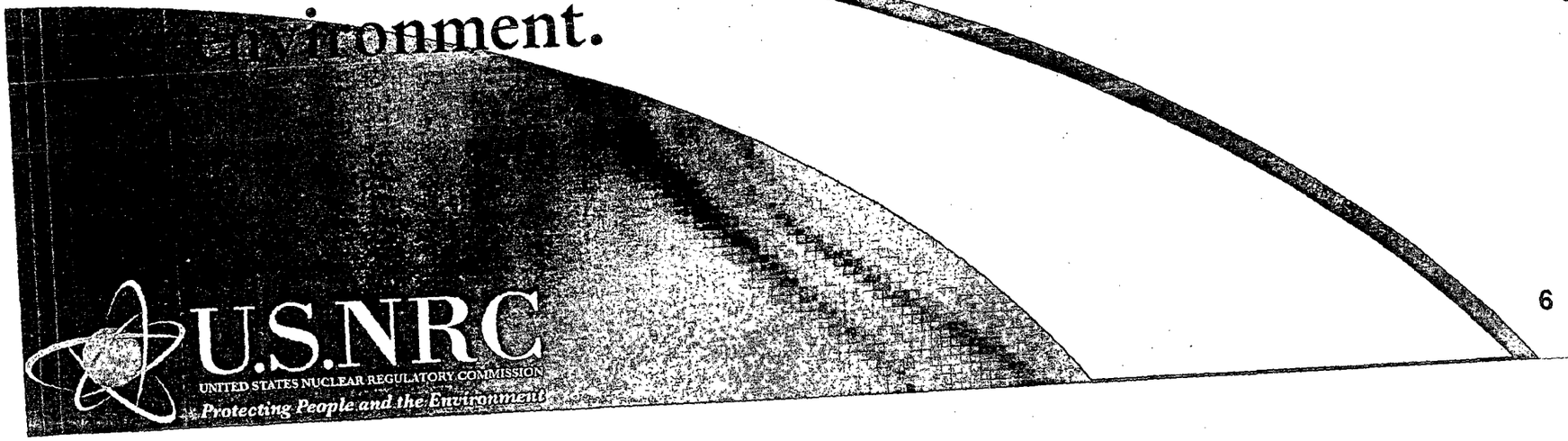
Protecting People and the Environment

Impact of NRC Comments

- Many NRC editorial and specific comments contributed to significant improvements in text.
- Further clarifications of constraints, and their use.
- Stated that collective dose should not be used for risk assessment, but did not provide quantitative guidance.

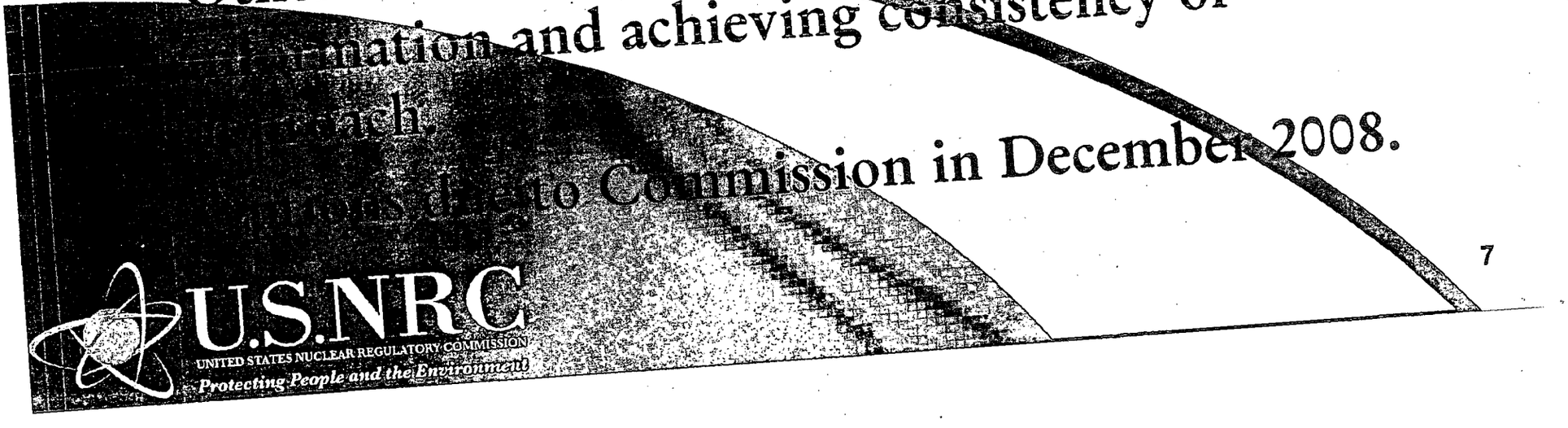
Impact of NRC Comments

- Continued to rely on unpublished or non-publicly available material.
- Continued with tissue weighting factors for 13 tissues within the "remainder".
- Included chapter on protection of the environment.



NRC Staff Next Steps

- Initiation of staff work to prepare options for Commission consideration.
- Considerations go well beyond 10 CFR Part 20.
- Changes do not directly increase adequate protection or safety.
- Other rationale, such as updating scientific information and achieving consistency of approach.
- Papers due to Commission in December 2008.



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Protecting People and the Environment

Advisory Committee on Nuclear Waste and Materials (ACNW&M) Questions on Corrosion of the Waste Package and Spent Nuclear Fuel Dissolution

In Response to Staff Presentations to ACNW&M in 182nd Meeting, September 18 – 20, 2007

Presented by T. Ahn of NRC and prepared by team members of engineered barrier system in post-closure, ENG 1, ENG 3 and ENG 4 of Division of High-Level Waste Repository Safety of NRC and Center for Nuclear Waste Regulatory Analyses (CNWRA)

186th Meeting of the ACNW&M, February 12 – 14, 2008
U.S. Nuclear Regulatory Commission, Rockville, MD

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

ACNW&M General Comment

"The most important considerations in any corrosion discussions to the Committee are: (1) what radionuclides (at what activity) are released from the Waste Package (WP), and (2) how are they released. The following questions are directed towards these considerations."

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Protecting People and the Environment

Examples of Releases and Release Modes

- What is potentially released depends on physical state and chemistry of spent nuclear fuel (SNF) radionuclides:
  - Rapid release of gap and grain boundary radionuclide inventory, such as C-14, I-129, Cs-135, and Tc-99.
  - High solubility radionuclide inventory, such as I-129 and Tc-99 (release controlled by SNF dissolution rate).
  - Low solubility radionuclide inventory, such as Np-237, Pu-(239-240), and Am-241 (release controlled by solubility limit or colloids).

- Potential release modes:
  - Advective or diffusional, depending on groundwater flow rates through perforations or cracks of the WP caused by corrosion
  - Advective or diffusional release is also in series with SNF dissolution rate or radionuclide solubility limit (or colloids).

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Question (Q) 1: Use of Temperature as a Time Surrogate

- Experiments at temperature to simulate long times were not used for NRC corrosion and SNF studies.

- Temperature could be used as a time surrogate, as rates of important chemical reactions increase predictably with temperature (e.g., Arrhenius relationship).

- Range of calculated repository temperatures, ~ 35 – 240 °C (~ 95 – 464 °F), used in experiments for
  - Kinetics of general corrosion
  - Localized corrosion criteria
  - Kinetics of SNF dissolution

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Q 2: Potential Staff Use of Corrosion Experiments Conducted since 2003 in License Application (LA) Review and Performance Assessment (PA)

- Use of CNWRA information to assist LA review depends on what information is provided in LA.
- Independent information could be used to assist LA review for areas such as:
  - Data and model justification
  - Data uncertainty
  - Model uncertainty
  - Model support
- Topics investigated on Alloy 22, since 2003, include (references in the end):
  - General corrosion
  - Seepage groundwater crevice corrosion
  - Dust deliquescence corrosion
  - Stress Corrosion Cracking (SCC)
  - Microbially influenced corrosion
  - Effects of fabrication processes

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Q 3: Application of WP Passivation Studies

- Passive film persistence – Chromium-rich oxide film results in low general corrosion rates.
  - Thermodynamic analyses used to assess long-term stability of passive film (Jung, et al, 2007; Mintz, et al, 2007).
  - Analogs: Josephinite, meteorite, and reactor steam generator materials were assessed to understand long-term passivity (Jung, et al, 2007; Ahn, et al., 2007).

- Anodic sulfur segregation – Although sulfur may remain on the surface during corrosion and destabilize passive film, molybdenum may dissolve sulfur and chromium promotes repassivation.
  - Scratched metal exposed to solutions containing sulfides or thiosulfates may experience sulfur-enhanced general corrosion (i.e., Jung, et al, 2007; Ahn, et al., 2007).
  - Sulfur impurity may be up to 100 ppm. Detrimental effects of sulfur segregation can be reduced by reduction of initial sulfur content in the alloy (e.g., 1 ppm) (Jung, et al, 2007; Ahn, et al., 2007).

- Alpha radiation effects – Effects on passivity appear limited.
  - No significant source of alpha particles to contact the passive film. Alpha particles inside WP cannot penetrate through the WP under nominal conditions, and there is no other significant source of external alpha-particles.
  - Possible alpha particle source is from early-failed adjacent WP, or from portion of adjacent WPs subjected to corrosion or mechanical failure. Unlikely geometry is required for possible effect.
  - Limited analyses are being performed, to support review of DOE's Features, Events, and Processes (FEPs).

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Q 4: Basis for Dust Deliquescence Corrosion

- Staff needs to review basis for potentially included and excluded FEPs.
- Alloy 22 corrosion testing in salt brines (potential composition of dust deliquescence brines) shows that general corrosion could occur (Yang, et al., 2007). Models of cathodic capacity of Alloy 22 in dust deliquescence brines (Shukla, et al. 2007) support the experimental observations.
- During the potential brine period, dust will be present. Although corrosion by seepage groundwater may dominate, dust deliquescence effects on general corrosion contribute to variability and uncertainty in PA.

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Q 5 and 6: Corrosion During Dust Deliquescence and Brine Periods

- In the dust deliquescence corrosion period capillary retention of dust deliquescence brines by rock dust may reduce the amount of brine that contacts a metal surface, but does not prevent corrosion from occurring (He, et al., 2007).

- In the brine period, temperatures appear high enough to form concentrated brines that may cause crevice corrosion. Simultaneously, general corrosion continues. General corrosion rates are generally insensitive to brine concentrations.

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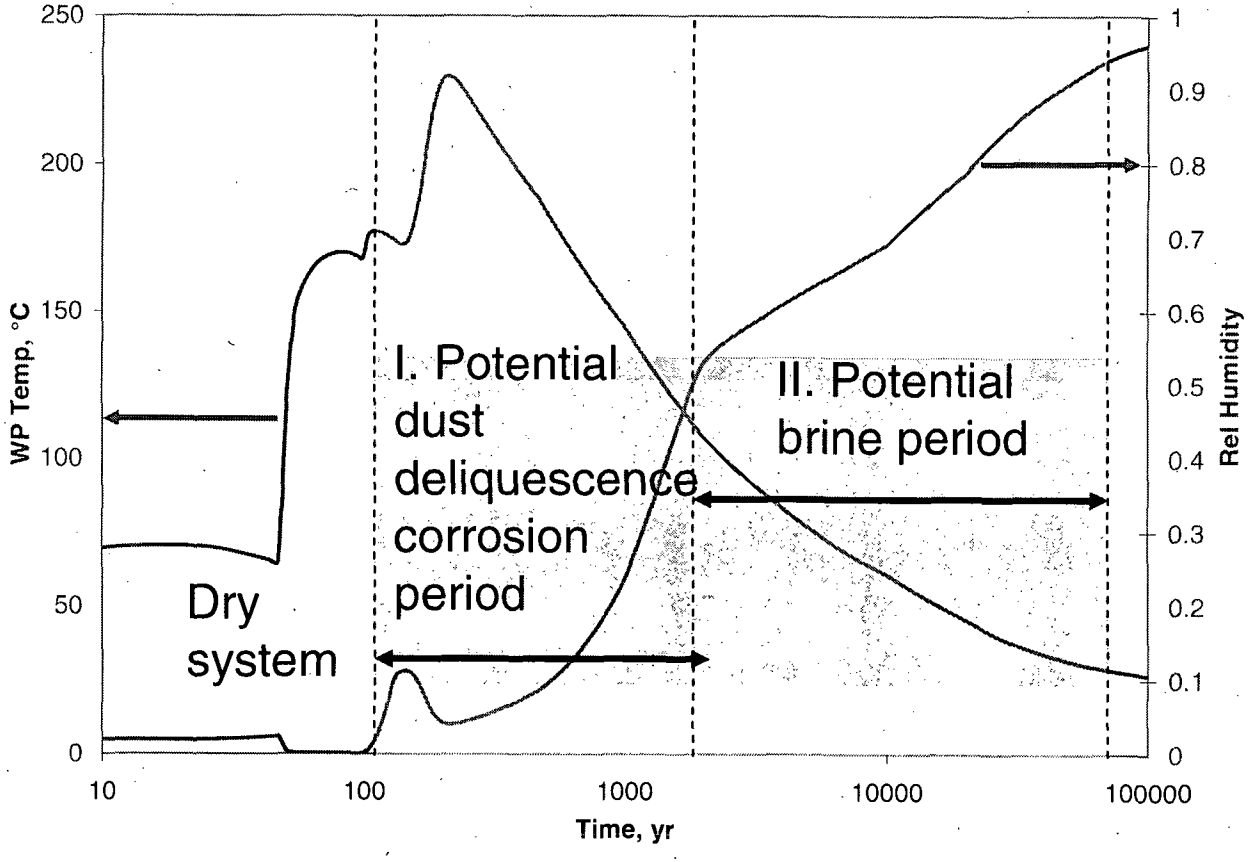
WP Environment and Corrosion Modes



(After Pensado, 2006)

- **Persistence of long-term passive film in general corrosion (I, II, and longer period)**
- **Dust deliquescence corrosion (I)**
- **Seepage water brines - crevice corrosion (II)**

(100 °C = 212 °F)

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Q 7: Role of Stress Corrosion Cracking

- SCC could potentially have an effect by allowing a limited amount of water into tight cracks in the WP.
- Formation of SCC requires carbonate/bicarbonate solution concentrations that are not expected in the potential repository (e.g., Chiang, et al., 2007). CNWRA analysis supports that SCC is an unlikely process (e.g., Chiang, et al, 2007).
- Uncertainties associated with SCC model abstraction are considered in TPA (Leslie and Grossman, 2007).

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Q 8: Chemical Mechanisms for WP and DS Corrosion.

- Corrosion most is the likely process to penetrate the WP.
- General corrosion likely will occur over a longtime.
- General corrosion may eventually create large enough opening in WP to support advective release.
- Passivity loss for enhanced general corrosion:
  - Impurity segregation (e.g. sulfur), corrosion product accumulation, or stress developed
  - Long-term dissolution and no repassivation

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Q 9: Nitrates in the Repository

There are two likely sources of nitrates in the potential repository:

- Atmospheric aerosols could be entrained in ventilation air and deposited, together with dust particles, on the waste package surface during the preclosure period.
  - The soluble fraction of atmospheric aerosols over continental landmasses typically is dominated by nitrate, sulfate, ammonium, and sodium (e.g., Seinfeld, 1986).
  - Nitrate concentrations in leachates of dust samples taken by the U.S. Geological Survey from the Exploratory Studies Facility at Yucca Mountain range from several tens to about 1800 ppm (Bechtel SAIC Company, LLC, 2004).

- Nitrate dissolved in groundwater.
  - Nitrate concentrations reported by the U.S. Geological Survey (Yang, et al., 1996, 1998, 2003) for porewaters extracted from rock samples taken from the unsaturated zone of YM and vicinity typically are in the tens of ppm.
  - Although these porewaters are initially dilute, evaporation may increase or decrease the concentrations of dissolved constituents, including nitrate salts.

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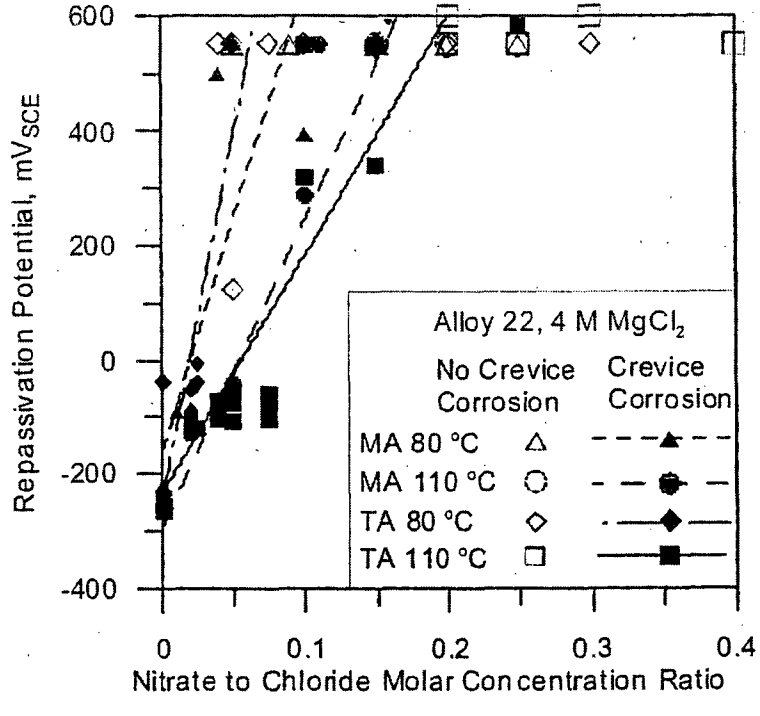
Q 9:Nitrates in the Repository (Cont.)

E_{repass} vs. NO_3 (Dunn, et al, 2005)



Crevice Corrosion Repassivation Potentials for Mill-Annealed and Thermally Aged Alloy 22

80 °C (176 °F);110 °C (230 °F)

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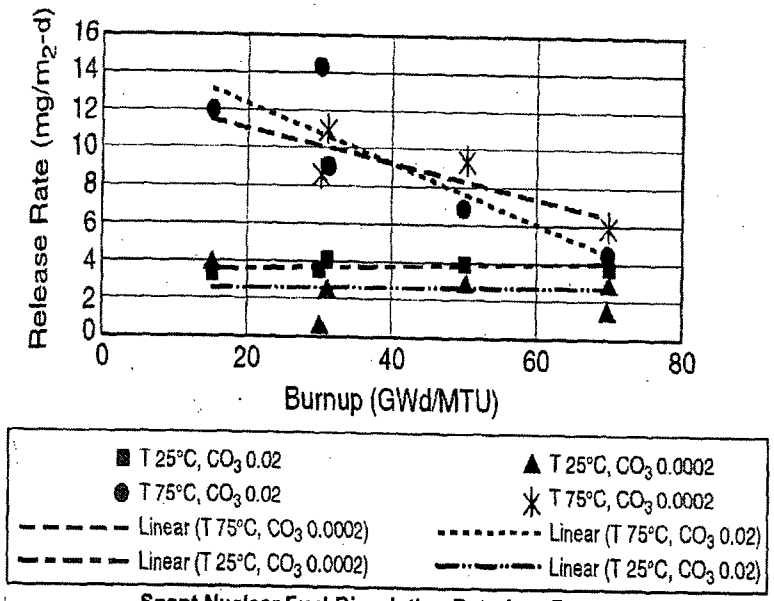
Q 10: Dissolution Rates for High Burnup Fuel

- Available information indicates that high burnup SNF does not increase the dissolution rate.



Spent Nuclear Fuel Dissolution Rate As a Function of Burnup Under Different Temperatures (T) and Molar Total Carbonate Concentrations (CO_3).

(Jain, et al., 2004)

- Available information indicates that:

  - prior dry oxidation of high burnup SNF may increase surface area, to increase dissolution rates (Ahn, 1996).

  - hydride formation (Pan, et al, 2007; Ahn, et al., 2007) does not affect dissolution rate, except potentially altering surface area.

75 °C (167 °F); 25 °C (77 °F);
mg m^{-2} d^{-1} = 1.42x10^{-9} lb in^{-2} d^{-1}

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Q 11: Use of SIMFUEL Data

- Dissolution rates of SNF, unirradiated UO_2, and SIMFUEL are undistinguishable for similar environmental conditions. Thus, dissolution experiments using unirradiated UO_2 or SIMFUEL are considered appropriate (Ahn and Mohanty, 2007; Jegou, et al., 2001; Shoesmith, 2000; Serrano, et al., 1998).

- Radiolysis effects on SNF dissolution may be significant in reducing environments. The potential Yucca Mountain repository is oxidative, not reducing, with abundant buffered oxygen available. Therefore, radiolysis is anticipated to have a negligible effect on an oxidized system.

- Uncertainties regarding the geometry of alpha particle emission after potential container failure appear low but are being considered (Ahn and Mohanty, 2007; Jain, et al., 2004).

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Q 12: Long-Term Spent Nuclear Fuel Behavior

- **Long-term stability of irradiated UO_2 matrix** – Other than chemical degradation (e.g. dissolution), ongoing work in Europe indicates long-term stability of crystal structure/integrity and stable radionuclide distributions.

- **Physical degradation** – Physical degradation could come from alpha displacement damage or mechanical failure, sometimes assisted by chemical process such as hydration in the irradiated UO_2 or hydrogen embrittlement in cladding.

- **Stability of cladding** – Cladding could be subject to gross rupture or perforations (e.g., pin holes and hairline cracks) by applied stress, hydrogen embrittlement, or corrosion through time.

- **Hydriding** – Hydrogen embrittlement in cladding comes from the formation of a brittle zirconium-hydrogen compound (i.e. hydride). Existing hydrides after reactor discharge could be reoriented radially under applied stress. More radial hydrides could form by absorption of hydrogen during corrosion, which could reduce cladding ductility or cause slow crack propagation.

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Q 13: Risk Insights Radionuclide Release

- Fundamental risk insights (NRC, 2004) have not substantially changed in light of new information.

- Radionuclide release depends in part on extent of the surface-area opening on WP.
  - Small surface-area opening for groundwater entry into the failed WP.
  - Limited groundwater volume restricts the mobilization of radionuclides.
- The expected extent of surface-area opening for various corrosion modes includes:
  - General corrosion - loss of passivity gives relatively large opening; may lead to advective release
  - Crevice corrosion – restricted opening from susceptible water chemistry, tight crevice area of buckled DS and WP, and weld area; may lead to diffusional or advective release
  - Unlikely SCC – restricted area opening; may lead to diffusional release

- New internals of WP to reduce colloid production

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