Official Transcript of Proceedings ACNWT-0204

NUCLEAR REGULATORY COMMISSION

Title: Advisory Committee on Nuclear Waste
183rd Meeting

PROCESS USING ADAMS
TEMPLATE: ACRS/ACNW-005

SUNSI REVIEW COMPLETE

Docket Number: (n/a)

Location: Rockville, Maryland

Date: Tuesday, October 16, 2007

Work Order No.: NRC-1819 Pages 1-300

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UNITED STATES NUCLEAR REGULATORY COMMISSION'S

ADVISORY COMMITTEE ON NUCLEAR WASTE & MATERIALS

October 16, 2007

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE AND MATERIALS

(ACNW&M)

183rd MEETING

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TUESDAY,

OCTOBER 16, 2007

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VOLUME I

The meeting was convened in Room T-2B3 of Two White Flint North, 11545 Rockville Pike, Rockville, Maryland, at 8:30 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:

LATIF HAMDAN
NEIL M. COLEMAN
MICHAEL LEE
GOUTAM BAGCHI
MYSORE NATARAJA
MAHENDRA SHAH
ANDREW MURPHY
BRITT HILL
DAVE CHERCHINSKY
MICHELE KELTON
TIM McCARTIN
JOHN FLACK
DAN TAYLOR
PHIL REID
ALEX SMIRY

ALSO PRESENT:

JOHN STAMATAKOS
LEON REITER
KEVIN COPPERSMITH
ROD McCUOLLUM
ANDY KADAK
ERIC LOEWEN
EARL SAITO
NICK APTED

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P R O C E E D I N G S

8:31 A.M.

CHAIRMAN RYAN: We will come to order, please. This is the first day of the 183rd meeting of the Advisory Committee on Nuclear Waste and Materials. During today's meeting, the Committee will consider the following:

(1) ACNW will have a working group meeting on preclosure seismic analysis evaluation at the proposed Yucca Mountain repository;

(2) GE-Hitachi Nuclear Energy Spent Nuclear Fuel Recycling Processes.

Mike Lee is the Designated Federal Official for today's session. Is he here? He's coming. Okay.

We have received no public comments or requests for time to make oral statements from members of the public regarding today's session. Should anyone wish to address the Committee, please make your wishes known to one of the Committee staff.

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

It is also requested that if you have cell phones or pagers that you kindly turn them off.

Feedback forms are available at the back of the room for anyone who would like to provide us with their comments regarding this meeting.

Without further ado, I'll turn this session over to our leader for this session, Professor Hinze.

MEMBER HINZE: Thank you very much, Dr. Ryan. This morning and early afternoon we will be involved in a working group meeting on preclosure seismic analysis evaluation at the proposed Yucca Mountain repository.

The purpose of the working group meeting is to receive briefings and to develop discussion that will aid the Committee in understanding the regulatory framework and the associated acceptance criteria to be used by the staff in their analysis of preclosure seismic hazards at the proposed repository. This is needed because of the mandatory use of new procedures as prescribed in 10 CFR 63 based upon risk-informed and performance-based approach.

Secondly, there are the concerns regarding the relative stringency of these methods as used at Yucca Mountain as proposed for use at Yucca Mountain in comparison to those used in seismic hazard analysis at other nuclear facilities.

The NRC in September of '06 prescribed procedures that will be used for their evaluation of the license application and their Interim Staff Guidance 01.

You will remember that in November of last year 2006, the NRC staff made a presentation to the Committee on this topic and specifically described the Interim Staff Guidance and the procedures that they used to develop it.

We learned in the ensuing discussion that there were concerns of the nuclear power industry with the guidance. As a result, the Committee invited the Nuclear Energy Institute and the Electric Power Research Institute in December '06 to present their views on the Interim Staff Guidance. And there was considerable discussion that followed that presentation and those public transcripts are available.

Subsequent to those meetings there has been continuing discussion on this issue among the NRC, the nuclear power industry, and DOE. In addition, Brookhaven Lab has completed a review of the American Society of Civil Engineers consensus standard on seismic hazard analysis at nuclear facilities and as a result of these additional communications, we have further information available, and thus the working group meeting should be helpful to the Committee and hopefully to others as well.

There are commonalities between the staff's guidance and the 2005 consensus standard of the American Society of Civil Engineers and we need to bring this out and we also are very much interested in learning from Dr. Stamatakos about the use of that standard at the Savannah River MOX facility study of seismic hazards and see what lessons we can learn from the application of the standard to that facility.

I should say to the presenters that sometimes the seismic terminology becomes rather abstract and is not commonly known, perhaps to the Committee as well, and there are a number of acronyms that we throw around rather liberally. So in your presentations I would hope that you would make certain that have a clear definition of all of our acronyms and our specialized nomenclature.

Also, I'm told by Mike Lee that the titles of the presentations that are in your agenda may not be consistent with those of the presenters and so please be alert to any changes in the titles.

To assist the Committee in its review of this topic, we have seated at the Committee table two invited experts that are well known, I think to essentially everyone in the room, Dr. Andrew Murphy, and Dr. Leon Reiter.

I'm going to briefly give a bio on them. I using the precis of the brief precis, but I want to make certain that we do have in the record that these gentlemen are well qualified to help us in this regard.

First, Dr. Murphy has been with the NRC's Office of Nuclear Regulatory Research since 1979, serving first as a research seismologist and later as branch chief. During that time. Dr. Murphy has worked on or been responsible for several of the regulatory products associated with the evaluation seismicity at NRC licensed facilities. Among these projects are the development of the Regulatory Guides 1.165 on reference probability and 1.208 on performance-based seismic siting for nuclear power plants.

Dr. Murphy serves currently as chairman of the NRC seismic issues technical advisory group and the chairman of the Nuclear Energy Agency's seismic group.

Dr. Reiter has over 30 -- that probably should be 50 --

(Laughter.)

-- sorry. Thirty years' experience in issues related to earthquake hazards. He has served in senior level technical positions at NRC from '76 to '90, and subsequently until 2006 with the Nuclear Waste Technical Review Board of the DOE. While at NRC, he was involved in the analysis and review of seismic hazards at nuclear facilities in most of the states and provided assistance to eight foreign countries.

Dr. Reiter has had the lead technical responsibility for the application of state-of-the-art methods to regulatory problems such as probabilistic seismic hazard analysis, numerical ground motion modeling, etcetera. Dr. Reiter is the author of the well-used and respected book, Earthquake Hazard Analysis, Issues and Insights.

With that, we -- unless there are questions by the Committee, we will move ahead to our first speaker who is our very own Mike Lee. Mike has been with the Committee with staff since 2001. He has degrees in geology as well as civil engineering and has been actively engaged in preparing an overview of the history of the development of seismic regulations in the Commission. And Mike will be presenting an overview of that for us this morning which forms the basis of further discussion. This is in draft form, as I believe Mike will explain and we are interested in comments and suggestions on how this can be improved and it hopefully will be of use, not only to the Committee, but to others as well.

With that, I'll turn it over to you, Mike, if you would, please.

Incidentally, there should be handouts on all of the talks -- that's a question. And so if you don't have one, raise your hand or go to the back of the room and they'll be back there.

Please, Mike.

MR. LEE: I've got all of my tools, so I'm ready to go.

As Dr. Hinze pointed out -- I'm not going to repeat Dr. Hinze's introductory remarks, but I think one of the -- I think it's fair to say that a number of questions have come up recently in terms of what does NRC require of its licensees in the area of seismic design. In looking at that question, there's another question that could be derived, how does the staff arrive at its decision making. And then last, how does NRC's performance compare with the other regulatory frameworks, if you will, that exist throughout the Agency for the licensing of nuclear facilities?

To get some answers, we thought it might be useful to look at the literature, going back to first principles. We examined public sources of information. Our review included, but was not limited as a first step the NRC regulations themselves, then walking backwards, the state of the considerations that appear in Fedreal Register. There's usually a draft and final rule and as everyone knows, there's a lot of information in the background information, if you will that goes to the Fedreal Register.

We looked at review plans, regulatory guidance, staff positions, SECY papers, Technical Assistance Reports that were prepared in support of some rulemakings and other regulatory products, as well as the scientific journals.

What we found is that NRC's seismic criteria vary. They vary by the type of facility that you're looking as well as the prevailing regulatory framework in place at the time the regulation was developed.

There are a number of reasons, I think it's fair to say why these regulations vary, the criteria vary. There's been, of course, an evolution in earthquake engineering science and technology.

There's also differences in the type of facility that you're trying to license; the hazard varies at different types of facilities. It's not a consistent hazard, if you will.

In looking at different types of facilities, it became clear that you could organize them by these subject areas. You have facility types. You have regulations that correspond to the facility types. And then there's a seismic event of regulatory interest. And this is my language. It's not a regulatory definition, but if you go back to the regulations, you'll find that earthquakes are described in a variety of different ways. I'll just pick them apart, Part 60, even though it's not in effect any more for Yucca Mountain, it came up in the context of potentially adverse conditions. When Part 60 was revised to be site-specific, it became a feature of that process.

In the context of nuclear power plants, generally it's the maximum historic earthquake is what the regulations are asking the licensees to examine. Geologic or seismological characteristics and so on. So you have different types of vernaculars or nomenclature, if you will, that describe a seismic event.

When you look at -- when you go one level below the definition, you look at the criteria, you can -- there's a couple of things being asked for, typically by the regulations. You have a specification of some kind of design earthquake and a minimum ground acceleration.

For nuclear power plants, repository, there's two levels or two tiers, if you will. In the case of the nuclear power plants, you have two sets of regulations, one governing existing regulations, one for future regulations. For the repository, of course, there was the pre- site-specific regulation and then we know how Yucca Mountain specific regulations. If you go into the literature, you'll find these numbers, I believe.

So what are our next steps? Well, the next step as Dr. Hinze pointed out is we're pulling together a report. We intend to issue it as a background paper and have attempted to focus on the facts and the history without getting into any editorializing or reviews of whether staff or management should have turned left or right when it came to a decision point. This background document, if you will, is intended as a literature review and doing so it provides a management tool supporting the Agency's goal of knowledge management.

Because we're just reporting the facts without any real interpretation, we don't consider this to be a legal or regulatory decision making type of document, so in that regard, we don't think it has any -- it will have any legal or regulatory standing.

The time table for this review, once the basic writing is complete and we intend to coordinate internally with the various program offices to make sure we've got our facts correct, we hope to issue it as a draft report in the November-December time frame. At that time, we'll see if the focus is an external peer review. We already have a limited internal peer review undergoing right now. And then we'll issue it as a final NUREG.

This slide is just to give you an idea of what -- how the information is kind of laid out in terms of the history, if you will. One of the comments I've gotten is you should probably include a time line in this report and I think, I know we're going to do that, but in thinking about it, I don't know if the time line is the right way to kind of organize this information or more like an event tree. Because if you look at the literature, there's certain key events that are kind of driving the train. Cornell's paper in '68, the USGS' assessment, reassessment, if you will, the Charleston earthquake in the late '70s, early '80s and the work that the Survey was doing independently of regulatory licensing and NRC; the experimentation, if you will, with expert judgment by the RAND Corporation. If you begin to kind of connect these dots, you have things just don't happen and I think it might be considered a series type of arrangement. Things are kind of -- looked like an event tree or fish bone type of arrangement.

So we tried to organize the information, if you will, from the literature sequentially, but we're going to, of course, put in these diagrams to kind of show how all the dots connect. We have a series of appendices. One of these, I think, I'm going to drop which is appendix B which is a discussion of the Mercali and Richter Scales. I think we' really need to do that. That's one of the review comments I got. But one of the comments I did get was a need to focus more on the evolution of NRC's Yucca Mountain program and the history of the seismic activity that took place there. It's addressed in the body of the text. One of the comments, as I said before, there is always a need or a recommendation to kind of expand that review and I intend to do that.

I don't know. That's about it. We looked at the literature and a lot of what you're going to hear today, I think, is covered by our report. When it becomes available, if -- we'll post it on the website. If you've got a real interest in looking at it, leave me your card today before you leave, and I'll make sure that you get a copy once it is available.

That's about all I have. Questions?

MEMBER HINZE: Thanks very much, Mike.

Does the Committee have any questions or I should say suggestions. You've seen the very preliminary draft of this. Do you have any recommendations that you wish to make now or give to Mike at a later date because we do want to close this out in the near term.

MR. LEE: Right. I should just also add if you read the low-level waste white paper on the history of low-level waste regulation, the tenor and the level of writing is similar to that. It just, as I said before, we're just presenting the facts without any real spin, if you will.

CHAIRMAN RYAN: It sounds good to me.

MEMBER HINZE: Do either of you gentlemen

-- have you had a chance to look at it and will you be sending reviews to Mi.e?

MR. MURPHY: I definitely had a chance to read it and have made some comments on it at this stage which I will send to Mike shortly.

MEMBER HINZE: Great.

MR. REITER: I also looked at an earlier version and I assume there's another version.

MEMBER HINZE: Unless there are further questions, thanks very much, Mike. And we look forward to this coming to fruition.

With that, even though we're ahead of time, I would like to suggest that we move ahead and the next speaker is Goutam Bagchi, who will be discussing current seismic design requirements for nuclear power plants.

Mr. Bagchi is Senior Advisor in the Division of Site and Environmental Evaluations, Office of New Reactors at the Commission. He has been involved in the design construction and inspection of numerous nuclear power plant structures and systems and components, the SSC, for over 40 years. He has been involved with a number of NRC initiatives on seismic design criteria and regulatory guidance, operating license design certification and the early site permit reviews.

Mr. Bagchi has a master's degree in Mechanical Engineering and Structural Engineering and is a Fellow of the ASCE.

Mr. Bagchi, we're pleased to have you here and we're anxious to hear what you have to say and we have your handout and the floor is yours, please.

MR. BAGCHI: Good morning, everyone. As Dr. Hinze pointed out, I am going to talk about the design criteria for new reactors, those that were docketed after January 10, 1997.

This is the outline of my presentation. Since the design process includes consideration of both the demand and the capacity, I have included a very brief discussion of the process of arriving at the capacity which is part of the design.

For the current seismic requirements, the regulatory criteria in 10 CFR Part 100.23, geologic and seismic siting criteria. Obviously, these are obviously site-specific. And 10 CFR 552 Subpart B is the standard design certification. Subpart A is early site permit. And I wanted to emphasize the aspect of the standard design which requires high level of generic design factor because the vendors want to produce a design that could be sited on multiple sites.

Both the hazard-based and performance-based approach are acceptable for the assessment of site-specific seismic loads. Probabilistic seismic hazard analysis forms the backbone of both approaches and I will describe the regulatory guidance associated with the two approaches in the next slide, the next two slides.

PSHA which is probabilistic seismic hazard analysis, it characterizes the hazard for hard drop condition or a shear-away velocity of 2.8 kilometers per second. However, site condition for layers of material overlying the hard material are frequently softer. Consequently, site response analysis is an important part of the characterization of ground motion at the free surface in the free field.

The reference probability-based seismic load is discussed in Regulatory Guide 1.165 and it is a hazard-based approach as pointed out on the slide. And this approach was based on the recognition that average of seismic hazard, a diverse set of reactor sites should be satisfactory for seismic hazard characterization at future locations.

Let me show that in the next slide. This is out of the Reg. Guide 1.165. On the horizontal axis it shows the probability of exceedence and on the vertical axis it shows the cumulative distribution. So it's an average of the demand for the sites at the time.

This is the other part of currently acceptable criteria. It is in Regulatory Guide 1.208. This was published in March 2007. It is based on the performance-based approach described in the American Society of Civil Engineers standard 43-05 that Dr. Hinze pointed out.

I want to emphasize that this adoption of the American Society of Civil Engineers standard is only with respect to the seismic demand, seismic load and the capacity determination as incorporated in ASCE 43-05 is not part of this endorsement by the NRC.

Brookhaven National Lab did a complete, as Dr. Hinze pointed out, a complete review of ASCE 43-05 that includes the load and the capacity determination and so forth. Except for the load, nothing is adopted by the NRC for the purpose of seismic design for nuclear power plants.

And in this performance-based approach, the probabilistic hazard for both 10^{-5} and to 10^{-4} mean are used to arrive at the design response factor and it ensures that the resulting design spectrum is risk consistent from side to side and covers frequency ranges for safety-related structures, systems and components.

Performance standard achieved is the frequency of exceeding an essentially elastic response at 10^{-5} per year mean.

This is a brief discussion of the relative conservatism of the capacity determination aspect of it. For example, the analysis model is damping values which are conservative. Earthquake time histories that envelope the response spectra which is frequently higher than the design response spectrum. Lowers the concurrent from accident conditions, pressures, temperatures, etcetera. Actual sizes are frequently greater than those required by allowable acceptance criteria provided by the industry codes and standards that are endorsed by the NRC guidelines in the Standard Review Plan. And these are all conservative acceptance criteria and overall response is essentially elastic.

NUREG-0800 which is the Standard Review Plan, was updated in March 2007 to recognize changes in design practices, industry codes and standards, etcetera. It provides guidance as stated in this slide. Based on lessons learned from the site permit application reviews, early site permit application reviews, staff recognized that in the sites in the Eastern and Central U.S. especially at MOX sites, the response spectra in the high frequency range tend to be high. The updated Standard Review Plan supplemented by interim staff guidance has provided a framework for considering the realistic effects of ground motion on structures with large footprints.

The point to make here is that the NRC criteria for capacity calculations are a little more conservative than those in the ASCE 43-05.

Seismic margin criteria came from a SECY document, SECY 93-087. The staff had proposed that there be a margin of about two times the safe shutdown earthquake, but the staff requirements reduced it to 1.67. So that is required as a seismic margin for the completed design of any new reactors that are now going to be licensed.

And this margin is based on high confidence, low probability of failure and this is roughly approximated to one percent failure probability.

So performance-based seismic is Regulatory Guide 1.208 and the seismic margin of 1.67, the mean seismic core damage frequencies are estimated to be between 5 times 10^{-6} and 1 times 10^{-6} per year. And the seismic core damage frequency for new plants with standard design which I described earlier with response factor, any response factor higher than most of the site events are going to be lower.

That's the end of my presentation and I can try to respond to questions.

MEMBER HINZE: Thank you very much. We appreciate it.

Mr. Croff?

VICE CHAIRMAN CROFF: I will try. In your slide four, you mention reference probability-based and performance-based and there's two different probability values associated with those. Is it correct that the use of the probabilities is the same. The only difference is how you get to the probabilities, how you derive them, but once you have the probability the path forward to show compliance is the same in either case?

MR. BAGCHI: The reference probability is mean annual probability -- I'm sorry, median annual probability and even at that time it was noted that it would be calculated to the power minus 14 per year. So they're roughly different, there was more correspondence with existing reactor SSEs. So the median value was adopted as a reference probability in Reg. Guide 1.165.

VICE CHAIRMAN CROFF: But once you get that probability, the path forward and analysis and the evaluation is the same?

MR. BAGCHI: The capacity determination is the same and the analysis is the same.

VICE CHAIRMAN CROFF: Okay.

MR. BAGCHI: But we did learn a few lessons from doing the early site permit reviews and it turned out that based on recent attenuation relations, in some cases, new information related to the seismicity of distant earthquakes like the Charleston and --

VICE CHAIRMAN CROFF: Madrid.

MR. BAGCHI: And Madrid, the response factor demand, the demand in seismic demand for 10^{-5} would be higher, more conservative.

VICE CHAIRMAN CROFF: Okay, moving on to your slide eight, and speaking of conservatisms, I was a little bit unclear. You list a number of items here. Is this list areas where you believe there is conservatism in the modeling and analysis?

MR. BAGCHI: I believe so. I have done analysis myself.

VICE CHAIRMAN CROFF: And I understood you to say that these analyses are probabilistic?

MR. BAGCHI: No. These are completely deterministic. Top of the slide it says deterministic.

VICE CHAIRMAN CROFF: Okay. Maybe I'm a bit confused. I thought earlier in the talk you said that these analyses were -- in either case were done with PRAs, maybe I missed a step here.

MR. BAGCHI: No. It was done by probabilistic seismic hazard analysis. That forms the backbone of both approaches. So you start with PSHA. Develop the demand. Once the demand is determined, the design and analysis of structure systems and components are completely deterministic that follow the Standard Review Plan, NREG-0800.

VICE CHAIRMAN CROFF: Okay. I understand that now.

Finally, you mention the ASCE standard and that the NRC just adopted certain aspects of it. Why not the whole thing?

MR. BAGCHI: It has to do what Standard Review Plan has adopted the regulatory guides with respect to demand, just like lower than ASCE. ASCE 43-05 allows some aspects of ductility that is not considered in the Standard Review Plan. And in order not to make a wholesale change at this point, staff did not endorse that portion of it.

VICE CHAIRMAN CROFF: Okay. Thanks.

MEMBER HINZE: Dr. Ryan?

CHAIRMAN RYAN: Thanks, Bill.

MEMBER CLARKE: No questions.

MEMBER WEINER: No questions.

MEMBER HINZE: Andy?

MR. MURPHY: No questions.

MEMBER HINZE: Good enough.

MR. MURPHY: We have gone through a whole lot of this, I'll say previously within the SITAG program, talking at various aspects of this process which is where we developed Reg. Guide 208 and I think Goutam has done a good job of summarizing the various aspects of it.

I don't think we have any further questions on some of the details at this stage.

MEMBER HINZE: Leon?

MR. REITER: Goutam, go back to slide four, and I'm just trying to straighten things out in my own mind. You talk about this reference probability base and performance base. I'm just thinking about the Yucca Mountain criteria, they may have a different definition of performance base, if I understand it. But anyway, how is -- the last line, how is the mean annual frequency exceeding earthquake load 10^{-4}, how is that performance based? I'm not sure I understand that.

MR. BAGCHI: It is based on PSHA. In Regulatory Guide 1.208 describes that. We use both the 10^{-5} and 10^{-4}. There are some aspect ratio that are determined from the two curves in order to ensure that from site to site variabilities are considered in that 10^{-4} frequency. It is to ensure performance of 10^{-5} frequency of significant, exceedence of significant --

MR. REITER: So the performance-based part is not -- is in what I guess is 10^{-5} chance of exceeding the frequency, the onset of significant and elastic deformation. That's the target.

MR. BAGCHI: That's the target of performance.

MR. REITER: So was generically determined that the 10^{-4} mean would be equivalent to that?

MR. BAGCHI: It would assure that and as I indicated in my previous slide, it would also -- on which slide, let me see. It does two things. Two things, seismic demand and structural capacity evaluation criteria laid out by the NRC Standard Review Plan ensure that conservatism to reasonably ensure conservatism to reasonably achieve both the following, less than one percent probability of an unacceptable performance, and less than ten percent probability of an unacceptable performance from ground motion equal to 150 percent of the site-specific response spectrum.

So this is because they both considered both 10^{-5} as well as 10^{-4} to derive the design factors and so forth.

MR. REITER: Okay, I'm just trying to straighten myself and maybe when we talk hear about it from the NMSS people. There, if I -- and I'm just trying to jump ahead and correct me if I'm wrong. There, the focus is on performance. And essentially somebody said they're not really interested in design load. They're interested in meeting the performance criteria. And I want to make sure --

MR. BAGCHI: The sequence probability.

MR. REITER: Sorry?

MR. BAGCHI: Based on sequence.

MR. REITER: I want to know, I'm trying to determine if there's a difference between what you're proposing here and what they're doing and that's what

I'm after.

MR. BAGCHI: The slides that are going to be presented by Dr. Robert Kennedy was not available here today, but he you know shows hopefully --

MEMBER HINZE: Let me explain. I should have explained this in my opening remarks. Dr. Kennedy has been kind enough to send to the Committee electronic versions of a manuscript on the use of performance-based acceptance criteria in future nuclear plants. In addition, he has provided to the Committee a set of slides that he had hoped to present here and because of various administrative problems has not been able to do that.

So those slides are available to the Committee and I'm sure to everyone else. The email that Mike, Leon, and I received from Bob said that we could use those in any way that we wished and so we'll hopefully be able to say a few -- Andy, you got a copy of those too. Hopefully, we'll be able to say --

MR. BAGCHI: I should stay away from answering any further questions on similarity with Yucca Mountain's --

MR. SHAH: May I add -- may I respond to your comment?

MEMBER HINZE: Please.

MR. SHAH: I'm going to address this issue in my slides. However, I'd like to make clear that Part 50 and Part 52, design basis is deterministic based on designing individual SSEs which are important to safety or safe category one, safety-related components.

The spectra, the difference between Reg. Guide 1.165 and 1.208 is how you select that design basis spectra. 1.208 is based on adjusting the hazard spectra to make it risk consistent based on where it is located. So the slope of the curve is taken into account so that you get that performance criteria at all frequencies of 10^{-5} per year, like frequency of onset of any elastic deformation. So that's still the design basis is still an individual deterministic for SSEs. No consideration of any event sequence and the risk, explicitly, but considering the margins we have, we expect - -that's the 43.05 study which concluded that you're going to get a factor of ten if you adjust the spectra for the location where the plant is. That's how it's selected.

In contrast to this requirement, Part 63 is based on probability of occurrence of event sequence, not just one individual SSC. If you have more than one, those will be taken into account. So that's a major difference. You cannot compare the 10^{-4} to whatever probability of one in 10,000 in the pre-closure period which is if you assume a hundred years, it's 10^{-6} per year. So you cannot compare directly because one is individual design deterministic design of SSEs. The other one is an event sequence probability of occurrence. So there's a major difference to the --

MR. REITER: The new Standard Review Plan, you're talking about 208?

MR. SHAH: No, I'm not talking about that. There is no Standard Review Plan, 1.208 guideline is still the determination of a design basis earthquake or SSC using the location of the site as the criteria, the slope of the curve. So the hazard spectra is adjusted to make it risk consistent. So you get 10^{-5} per year, probability of the frequency of onset of any elastic deformation.

MR. REITER: Goutam, this doesn't have to 10^{-4} mean if it's adjusted -- I'm just trying to find out the role that performance plays in determining --

MR. BAGCHI: Well, let's not forget that the design response spectrum is 10^{-4} mean, but it is derived by taking into account risk consistency.

But you have to go to -- if you look at

Regulatory Guide 1.208, it also describes how that is arrived.

MR. SHAH: But you can select any as a basis and then demonstrate just that spectra. You will have a higher factor to apply, design factor, they call ASCE 42.05. You will have a different higher design factor to arrive at 10^{-5}, so basis could be anything.

MR. BAGCHI: Actually, it effectively is less frequent than 10^{-4} if you take into consideration all of the frequency ranges.

MR. REITER: Just let me just finish this right away, because the difference between the working on a design basis and doing performance basis is really important. It's at the bottom of everything. I just wanted to make sure I understood what you're saying.

So you're essentially saying that a 10^{-4} was derived, generically derived as being consistent with the 10^{-5} onset of significant and elastic deformation. Is that --

MR. BAGCHI: That's correct.

MR. REITER: While in the waste, there is no reference 10^{-4} probability. Everything just seems to flow out of that thing. Okay.

MR. SHAH: Which I will be talking more also.

MEMBER HINZE: Good talk. I'd like to follow up on some of Allen's questions.

Regarding the ASCE standard, the NRC accepts this with respect to the seismic load and that's it.

What about other nuclear facilities? Is this being used? Will it be used? Is it incorporated? How does that interface with things other than nuclear power plants?

MR. BAGCHI: In DOE space, they're using it.

MEMBER HINZE: They are using it?

MR. BAGCHI: They are using it.

MEMBER HINZE: And what will the NRC do regarding this? Is there any effort being made to look at this, to expand the Brookhaven study other than nuclear power plants?

MR. BAGCHI: This is my personal opinion. I feel that just adopting ASCE 43-05 deterministic design criteria which are in 43-05 is really half a step. I think we need to look at the performance-based approach for design of structures as well, structures of performance. That will take some time.

It will evolve, and I think we should not personally, I don't think we should rush to change that. It may cause misunderstanding in the way design is performed and most of the standard designs have been performed.

MEMBER HINZE: In your slide eight, Allen had some questions regarding the conservative acceptance criteria. Are these designed to be conservative? And if so, what -- how is that determined? Conservatism has all kinds of bad connotations in many people's minds. How is your use of the conservative acceptance criteria used here?

MR. BAGCHI: When I wrote that attribute, what ran through my mind is how industry codes and standards come up with acceptance criteria. It's based on conservative bias on what leads to failure. For example, an allowable stress or an allowable strain, there is substantial conservatism in that.

MEMBER HINZE: These are based upon standards in the engineering world that -- and is there consistency in those conservatisms?

MR. BAGCHI: Consensus standard, there is consistency in those things. Even, for example, those components that are tested on shape tables. They are tested on test response spectra. There is conservatism on that as well. It escapes my mind right now. In the IEEE standard they have that.

MEMBER HINZE: Let me go to Slide 10 and I just want to make certain I understand and the seismic margins criteria, all new and advanced reactors are expected. Is that -- are they required? Or are they expected? What's the difference here? Why did you use expected?

MR. BAGCHI: It came right out of the SECY SRMs, Staff Requirement Memorandum. It is an expectation of the Commission, but that's good enough for the industry to adopt it.

MEMBER HINZE: Okay, that's good. Let me go to your last slide, the core damage estimate. This 5 to 1 times 10^{-6} per year, what's the reason for this range from 5 to 1? How significant is that? Where does it come from? How is it constrained, etcetera?

Can you expand upon that a bit?

MR. BAGCHI: Basically, we determined that by looking at the three early site permit applications. One was the North Anna site. Another was Clinton site. And the third was Grand Gulf site. The response spectra in rock sites tend to be high in the high frequency range, so if one generates the core damage frequency on the generic basis, then because the high frequency demand seems to be high, and using the previous lessons learned from the seismic PRAs, for some of those sites, it would be a little bit higher number that came from probably North Anna, five times 10^{-6} and one times 10^{-6} or less would be for source size and sites with much lower seismic hazard.

MEMBER HINZE: So this is the range of the sites as well as the frequencies involved?

MR. BAGCHI: Yes, sir. Core damage frequency.

MEMBER HINZE: Right.

MR. BAGCHI: Estimated core damage frequency.

MEMBER HINZE: How does the seismic core damage estimate compare with the damage to the SSCs? I don't understand where seismic core damage fits into this?

MR. BAGCHI: Well --

MEMBER HINZE: Help me.

MR. BAGCHI: Even if there is failure of one component, it does not lead to core damage.

MEMBER HINZE: That's right.

MR. BAGCHI: So the plant core damage frequency is based on the redundancies and the plant logic analysis and it might end up being dependent on two things. One of the things may be considerably stronger than the other, so based on that I would say that core damage frequency has at least about a factor of 10 on the 10^{-5} that has been a performance requirement for structures, systems, and components.

MEMBER HINZE: That's six times 10^{-5}?

MR. BAGCHI: Roughly.

MEMBER HINZE: Okay, right. Are there other questions?

CHAIRMAN RYAN: Bill, let me just mention for the record that we do have a tie line and I'm going to try to take inventory. Is anybody on our tie line?

(No response.)

No remote participants? Okay, I just wanted to make sure.

Thank you.

MEMBER HINZE: Except some of us sitting around the table, right?

With that, thank you very much. That's very helpful.

Now we turn to Mysore Nataraja. Dr. Nataraja is senior technical engineer in NMSS' Division of High-Level Waste. He is a charter member of that division and that says something. Joining the NRC in 1982 after leaving Dames and Moore Engineering firm.

Raj has had a series of very responsible positions within the division working especially on seismic design issues at Yucca Mountain. Raj has a doctorate in geotechnical engineering and we're very please to have him here again today and he's well-known to the Committee and we'll be discussing the preclosure seismic design and performance requirements for the Yucca Mountain repository.

Raj?

MR. NATARAJA: Good morning. As Dr. Hinze said, my name is Mysore Nataraja. If anybody calls me Raj, don't get confused. That's my nickname.

This presentation consists of two parts today. The part one which I'll be delivering and part two by my colleague, Dr. Mahendra Shah. And my presentation basically consists of a brief discussion of the regulatory framework that is part 63. And I will provide some background and past history about the interactions between NRC and DOE on this particular issue. And also I'll be talking about our interpretation, staff's interpretation of what constitutes an acceptance method for compliance determination and demonstration.

Part two, Dr. Shah will go into some

details about the interim staff guidance that we have developed, which will be used along with the Yucca Mountain review plan. As you know, the Yucca Mountain review plan was issued, revision two was issued in 2003, but we realized that there was a need for going into greater detail in the seismic design aspect and he will go into some of those details.

As Dr. Hinze earlier mentioned, in November 2006, we gave a fairly detailed presentation to the Committee. This is going to be a much shorter, abbreviated version of probably the same topics.

Slide 2 gives the outline of my presentation. I first will go into the purpose of my presentation and then I'll briefly cover the regulations that go in the preclosure seismic design and performance demonstration. I will touch upon some issues related to seismic hazard, but without going into great details. And then I'll briefly talk about the seismic design methodology. And I will summarize for you the Department of Energy's proposed approach for both the hazard assessment, as well as design, preclosure design, seismic design. I will also go into the feedback that we gave to Department of Energy's proposal and then I will finally summarize what the current status and what sort of agreements

NRC and DOE have come up with on this particular important topic.

Slide 3, the purpose of my presentation basically is to put this issue of seismic design and performance, performance demonstration in the context of the regulatory framework found in 10 CFR Part 63.

In order to understand the current status, we'll need to discuss the historical development of this methodology has developed over time. And with that background, we shall review the Yucca Mountain seismic design methodology and we'll conclude that has now developed an acceptable approach to reviewing what the Department might submit as a part of a potential license application for high-level waste repository at Yucca Mountain.

Okay, in slide four, this is the regulatory framework. In 10 CFR Part 63, there is a section, 63.112. That's the key to the performance demonstration for preclosure. 63.112 deals with the so-called preclosure safety analysis for short PCSA and this section goes into some great details. If I remember, there are about 13 parts to it. And it describes very clearly what a PCSA is supposed to be and how it should be conducted. It's fairly clear there is no ambiguity there as to what needs to be done by the licensee.

And in 63.112 there is a subsection (f). Under this section, there is the requirement for a description of description and discussion of a high-level waste repository design referred to, a terminology called GROA, Geological Repository Operations Area which consists of both the surface and the underground facilities. So the license application is supposed to provide a description and a discussion of the design. And that design also includes the seismic design. So the seismic design comes as a subset of that repository design. There are other aspects of design there.

Further under this section, we'll find a cross reference to the relationship between design criteria and 63.111(a). And 63.111(a) refers to the 10 CFR Part 20 requirements, that is the radiation safety which is common to all facilities licensed by NRC.

So 63.112 refers to 111(a) which is the design should meet the requirements of Part 20 during normal operations.

And finally, the rule also requires a demonstration of the relationship between the design bases and the design criteria and how the design achieves the performance requirements needed under PCSA. And it specifically calls for demonstration of performance under two categories of design basis events. They're called Category 1 and Category 2 event sequences. And the definition for Category 1 and Category 2 event sequences if found in 63.2. Simply stated, Category 1 event sequences are those which are expected to occur once, at least once or maybe many, many times during the operation period. And Category 2 is a less probable event, but likely to occur during the preclosure period. And the requirements, the performance requirements for the two categories are also defined. Category 1 event sequences, the PCSA should demonstrate clearly that Part 20 requirements are met and during Category 2 which is the sequences one chance in 10,000 of occurring during the preclosure period of the -- before permanent closure as supported in the regulation.

And there is a little bit of possibility of interpretation here because there is no specific period of preclosure period as defined. So one could talk about the actual waste emplacement period which can go anywhere between -- it acts about 50 years from the last day of the commence of the waste emplacement.

So if you have 20 or 30 years of emplacement operation, it adds another 50 years. So you can talk about clearly about 80 years as a minimum.

So for all practical purposes, generally we talk about preclosure period as consisting of about 100 years. So that is where you get the 10^{-6} event sequence for Category 2. And the performance measure for that is a hypothetical individual sitting at the boundary of the site should not get, should not receive more than five rems during that particular event sequence.

And the way which you demonstrate compliance is not through any of the design requirements. As you can see, there are no prescriptive design criteria. DOE has the option to start with any design and demonstrate compliance through conducting the PCSA which gives the option of either showing the Category 2 10^{-2}, sorry, 10^{-6} event sequence can be eliminated. That is the event sequence which is initiated by a seismic event can be eliminated by showing that the probability of occurrence is less than 10^{-6} or you can show that if there is a failure due to seismic event, the resulting dose is less than five rems, but doing a consequence analysis. That is all clearly defined in the PCSA.

That's the most important regulatory framework. That's really the first from the rest of the regulations. The demonstration of compliance is through either elimination of the event sequence or through the demonstration of consequence which is acceptable, five rems at the boundary.

Next slide. Now let's look how DOE has attempted to address this regulatory requirement for the seismic issue. The first part of the seismic design as discussed in the previous presentation is to come up with the seismic hazard. And the disciplines involved in the determination of seismic hazard and the seismic design -- various disciplines that are geologists, seismologists, structural engineers, and so on and so forth.

And the complexity is pretty -- the volume of information to be gathered is quite significant, so the Department of Energy proposed that a topical report would be written and in the topical report they would document the development of hazard, the methodology for the development of hazard, selection of the appropriate design levels and the design methodology and so on and so forth.

And what started as one topical report, eventually they broke it up into three parts. The first part was supposed to deal with the hazard assessment; the second with the design methodology; third with the design inputs. And the hazard assessment methodology took quite a bit of time. I think there are some people in this room who have been through that entire history. It started in the '90s and went on for almost 10 years or so. And along with the topical report which deals with the investigations, geological investigations for faults and other things, there was also a detailed probabilistic seismic hazard analysis methodology, PSHA methodology adopted using the expert elicitation according to the analysis procedure and all that.

So after a number of interactions and reviews and revisions and so on and so forth, topical report, the first part of the topical report and the PSHA report were reviewed by staff and staff found the methodology proposed by DOE was acceptable to us.

And then the next slide. The second topical report which was -- the first one, ran into some difficulties because in this time frame we changed from Part 60 to Part 63. And Part 60 had very specific design criteria. We had design basis events and it was based on deterministic design criteria. And Part 63, which is risk-informed and performance-based had no specific design criteria.

But this is where we had a lot of difficulty, because most of the engineers are very much used to thinking in the deterministic fashion. For them to switch over from the specific criteria to the performance-based approach, there was a lot of revisions required and a lot of interactions between NRC and DOE. And the last revision to the second topical report relays a number of questions because the approach given by DOE was not quite clear to us how they would show using the PCSA that the performance would be met, performance requirements would be met.

So Department of Energy, they provided their summary of the approach in a very important letter of August 25 in which they tried to address all the concerns and comments raised by the staff during the reviews and interactions.

So in the next slide, basically, I'll quickly try to summarize DOE's approach. That is DOE"s topical report. I think it is revision 3, along with the other 2005 letter, basically consists of the following approach: that is, they will select two design basis ground motions and they're termed as DBGM-1 and DBGM-2. That is Design Basis Ground Motion

1, Design Basis Ground Motion 2 to correspond to the Category 1 event sequence and Category 2 event sequence of Part 63. And in layman's terms it is approximately the thousand year return period earthquake, and a two thousand year return period earthquake. They call it as Frequency Category 1, Frequency Category 2. The terminology is confusing, but that's basically what it means.

The structure systems component referring to safety would be designed using these two levels of ground motions. And the design criteria that will be used would come from the standard of your plan, NUREG-0800 which is used for all plants. They are essentially elastic strain criteria and quite conservative.

In addition to performing this design, DOE proposed that they would conduct a Seismic Margin Analysis, SMA, very similar to the one that was described earlier and this basically uses a ground motion for the margin analysis, what they call beyond design basis ground motion, the BDBGM. And that uses an earthquake ground motion which is approximately two times what you might call a safe shutdown earthquake which is used for power plants. Basically, the same -- I forgot to mention 1.67, but they were generous enough to use two times. And the claim that supports base is that the combination of the design bases which are essentially similar to what is used for Part 72 which is an independent spent fuel, fuel storage facility available to the repository.

So the design criteria is justified on the basis of the similarity of risk with the Part 72, and then in order to fulfill the performance demonstration, they would do the SMA of the margin analysis using this methodology similar to what was used in the individual plant evaluation for external events, known as IPEEE for short. And this in combination, the design approach and the performance demonstration together would satisfy the regulatory intent defined in Part 63. This was the summary of DOE's proposal.

The next slide essentially, that was the turning point for the -- DOE gave its very specific understanding of how it would demonstrate compliance with the PCSA requirements and after a lot of debate, internal debate, within the staff members and the consultants, we found that this methodology fell short of demonstrating compliance.

Essentially, what we said in our letter of January 2006 to DOE was that we had no problem with the design bases and the design criteria that the Department of Energy proposed. The design bases are reasonable. The design criteria are reasonable. And we didn't have any problem with the SMA because SMA has been used by the Agency and no problem, except that we didn't consider that the SMA would be a substitute for demonstrating compliance for the PCSA requirements.

So we proposed in our letter that they need to do some additional analyses to meet the requirements and the intent of Part 63, specifically what is described in PCSA 112.

And we also referenced ASCE 43-05, that's the topic of the next presentation. He's go into big details. We talked that that methodology, if adopted, would in combination with their design be able to demonstrate and be an acceptable methodology to demonstrate performance with PCSA requirements.

And it gives specific options. Either you can do the event sequences to show that the event sequences are less than 10^{-6} in probability and therefore you don't have to do any further analysis, or you can change the event sequences by changing the design or adding additional features, etcetera. If that doesn't work you can demonstrate by doing a event sequence analysis and the particular individual sitting at the boundary will not receive five rems if there is a failure due to the seismic event sequence.

That was basically our feedback. And Slide 9 basically the current status is that we had a technical exchange on this topic in June of 2006 and the staff issued the interim staff guidance. The staff guidance is basically for us to follow how we are going to review what DOE might present, but DOE, after looking at the staff guidance and our presentations during technical exchange, came up, we came up with a consensus and DOE agreed to adopt this methodology in their design and performance demonstration. That's the current status.

So in summary, you can see that there has been a lot of history and DOE's design and performance demonstration methodology have developed over a period of time and things have been quite complicated because of changes in the regulatory approach that is going from Part 60 to 63, generic to site specific and deterministic to performance based approach. And the engineers on both sides, NRC and DOE, have taken a sufficient amount of time to digest and finally come up with an acceptable approach and the guidance has been published and DOE seems to be comfortable with this approach. Of course, we haven't seen exactly what they're going to do. That will be seen when we get the license application. And before I hand over to Mahendra, I will be happy to take any questions or you can wait until both f us are done. It's your choice.

MEMBER HINZE: Thank you very much, Dr. Raj. I for one found your discussion of the history of the development of this very informative. I think I now for the first time really understand what happened in the series of events and I think that's very helpful.

Let me ask you, regarding the DOE's response in June or July of this year in their topical report revision 5, your evaluation of that, I gather you're satisfied because it emulates, repeats the ISG methodology?

MR. NATARAJA: Actually, we have not reviewed the topic report, nor have we sent review comments on that. We have just acknowledged the fact that we received it. It was received recently and I am not quite sure whether we are going to review this as a topical report because we have been overcome events. And the topic report has a review methodology which takes about a year in terms of the review time needed to go through a lot of procedure and process and since they divided this into three parts, we will not be able to write an SER and we will not be able to reference our review in our license application anyhow. So the actual review will be done when we receive the license application, but at least we know that there is no disagreement between NRC and DOE on this issue as to how we can approach this and what would be acceptable to us.

We hope that that understanding is good enough at this time, but I'm not sure we can say whether everything is hunky-dory at this stage.

MEMBER HINZE: In formal conversations with DOE people, the impression I've received is that it fully complies with the ISGE 1 methodology.

I wonder if there is any representative from DOE such as Kevin Coppersmith --

(Laughter.)

-- that might have any comments to make about the topical report revision filed.

Kevin? Why don't you go right over here, Kevin, and sit down.

MR. COPPERSMITH: Shall I use this microphone?

MEMBER HINZE: You can indeed.

MR. COPPERSMITH: I'm Kevin Coppersmith. I'm consultant to the DOE, so I don't -- I'm not here in a capacity to present, but just to observe, but I'd be happy to observe in this case that yes, I think the methodology that DOE has developed in Rev. 5 of the topical report is very consistent with ISG 1 in overall methodology. There probably are some details that would be determined as we move through its application in the license application, but the spirit of a probabilistic approach to event sequence analysis, the adoption of design criteria that are consistent with facilities of similar risk significance. The use of Reg. Guide or of the Standard Review Plan, NUREG 0800 for basically developing excess capacity and conservatism. Those are all part of the methodology. So I would say that -- I would agree with Raj. I think we've worked out the rough spots in differences in methodology.

And it took a few years and a lot of interactions to get to that point.

MEMBER HINZE: Thank you very much, Kevin.

MR. SHAH: Raj, may I add something?

MEMBER HINZE: Please.

MR. SHAH: We have some questions about how they developed the fragility curves, but these are details that are now during the review. The plan was, and I don't know whether this is the latest plan or not, was to respond to DOE, giving our feedback, if any, the positive and whatever, some questions that we may have. That's a plan.

MEMBER HINZE: So we may expect some request for additional information.

MR. SHAH: I don't know whether that was discussed with DOE or not, but I've discussed with the project manager for this preclosure and that's what he was planing to do.

MEMBER HINZE: I have a further question, Raj, on another topic. You talked about the 50, 80, 100 years. This is -- gives us a 1 to 2 times 10^{-6} per year. I note in Bob Kennedy's use of this that he uses 2 times 10^{-6} per year rather than the 1 times 10^{-6} per year, what I'm used to seeing there.

And you mentioned now 80 years. That's the first time I've heard that. Can you just kind of expand upon should we be thinking about 1 or 2 times 10^{-6} per year?

MR. NATARAJA: I think the definition is very clear in the Category 2 sequences it's 1 in 10,000 before permanent closure.

MEMBER HINZE: Right.

MR. NATARAJA: So whenever the permanent closure happens, that determines the preclosure period, but for calculating frequencies, I'm pretty sure there might be some room for interpretation depending upon the active emplacement time where there is some scope for doses to the public. If there is no dose to public, the period by itself has no meaning. That's the spirit of the PCSA, actually something must be happening during which there is a seismic event, should result in a dose. If nothing is happening, I'm pretty sure they can take advantage of it, but right now, the reason I said 80 is the number formed for the active emplacement operation is about 25 to 30 years and the retrievability option needs to be maintained 50 years from the time when you start the emplacement, so the last emplacement, if it is in 30 years, then the last 50 years, and so you end up with 80 years.

So for all practical purposes people are using 100 as a reasonable number for preclosure. I think for PSHA demonstration if 100 is used, I don't think anybody will argue with that. That's my understanding.

MEMBER HINZE: I just wanted to get that on the record so that we all understood the differences between 1 and 2. You're talking about 1.3

now. But it's very -- it's a subtle difference.

The position is that the emplacement is roughly 30 years and then there's a minimum of 50 years open after that. That gives you the --

MR. NATARAJA: That 50 years can also change. Commission can decide it can be earlier.

MEMBER HINZE: I understand. I'm asking too much here.

May I pass it on to you, Allen?

VICE CHAIRMAN CROFF: I guess I'm not sure whether this is a question or a comment, but I've heard a lot of use of risk informed in this whole business and in looking at the criteria and the way this is set up, I just don't see much that's risk-informed here. by saying that the probability is 10^{-6} check mark and you can walk away from it irrespective of what the consequences of an event might be, I think you're out of risk-informed territory pretty quickly.

And when looking at risk informed, I'm looking for something that considers well the spectrum of probability and the associated severity of earthquakes and then translating that into what would the risk be at the person at the site boundary or whatever. I'm just not seeing any of that in any of these methodologies, frankly.

The regulations are cast and we're not going to change those. I mean it is what it is, but just a commentary I guess on my part. If any of you want to respond to that, fine. I'd be interested in your thoughts.

MR. SHAH: The reason it is risk-informed because they can select components to design to certain rigidity or certain strength and then eliminate all other components from coming into picture.

Like if you design the crane that will not drop or the cast which you're handling --

VICE CHAIRMAN CROFF: I would suggest that maybe you're describing performance-based as opposed to risk-informed.

MR. SHAH: It is based on the risk that if there is a failure of a component which may lead to release of radioactivity which is significantly low, then you don't have to worry about it.

VICE CHAIRMAN CROFF: It's deterministic. It can't be risk-informed.

MR. NATARAJA: There is a relationship between how the five rems at the boundary was chosen. That is based on the overall risk-acceptability. Tim McCartin is not here, so I don't want to turn to some data here, but I understand that was based on some overall requirements of radiation safety.

VICE CHAIRMAN CROFF: I will agree that the five rem has some relationship to risk and it is in my view a decent surrogate for it, but it's the other part, the probability exclusion part where you -- risk inform just goes out the window right there.

MR. NATARAJA: but they have the choice. They can --

VICE CHAIRMAN CROFF: I understand they can.

And as I said, it does appear to be performance-based. In other words, DOE can select how they go about trying to meet these criteria. That's performance-based. It's just risk-informed isn't there.

MR. SHAH: Risk-informed in a way if failure of a component is not going to result in a significant release or it will be less than five rem, they don't have to worry about it.

MR. NATARAJA: Dr. Hinze, I think Britt wants to say something.

MR. HILL: Britt Hill, NRC staff. You are correct, there is a difference in how risk-informed performance base is applied in Part 63 between pre-closure and post-closure. Where in post-closure, after a repository closure, we are looking at the likelihood of the event occurring, weighed into the potential radiological dose consequences.

And here it does give, it is a more deterministic binning of risk to where the risk either falls into a Category 1 or Category 2 event sequence. So there is like Mahendra is saying some flexibility, given that you're dealing with a Category 2 event sequence where in that chain of potential events you want to build in additional resiliency or add in additional factors in the event sequence. But in the end, it is strictly the dose itself with no weighting of likelihood of that dose outside of the two different Cat 1 and Cat 2 boundaries.

MEMBER HINZE: Thank you. That's helpful.

Dr. Ryan?

CHAIRMAN RYAN: All that is interesting and I'm glad you brought it up, Allen. I've been thinking about it for an hour or so. Does that result in overdesign or underdesign or adequate design?

MR. HILL: Britt Hill, NRC staff.

CHAIRMAN RYAN: That wasn't a question.

MR. HILL: It results in an adequate demonstration of the performance objectives.

CHAIRMAN RYAN: That wasn't a question.

(Laughter.)

MEMBER HINZE: Dr. Weiner.

CHAIRMAN RYAN: No, no. That wasn't my question.

Does this result in a tendency to overdesign or underdesign?

MR. NATARAJA: I think it is hard to say. It could be either way. It depends upon the particular design and what they have depended on to demonstrate compliance. You could end up being more design. It could end up being -- you know, it may be quite reasonable design without being unnecessarily conservative. It all depends upon how they choose to demonstrate compliance with--

CHAIRMAN RYAN: That was in the details of how they apply these principles.

MR. NATARAJA: Right.

CHAIRMAN RYAN: Okay, fair enough.

MR. NATARAJA: It's not meant to force them to overdesign anything.

CHAIRMAN RYAN: Okay, great.

MR. SHAH: My personal view is that it will be -- the design will be consistent with an HCR Part 72 design because you're not talking about design of an individual SSC which is important to safety, but as an event sequence.

CHAIRMAN RYAN: And I appreciate event sequence, yes.

MR. SHAH: More than one component. That's why I feel it would be not more robust than the facility for Part 72 or just for storage.

CHAIRMAN RYAN: And the fact that you are dealing with event sequences is a little bit more complicated problem, obviously.

MR. SHAH: It's somewhat more complicated.

CHAIRMAN RYAN: And try to compartmentalize that certainly has some merit. I appreciate that.

Thank you.

MEMBER HINZE: Dr. Weiner?

MEMBER WEINER: First of all, I want to thank Raj again for a very clear presentation of what to me were very complex and confusing regulations. So thank you.

You talk about a probability of 1 times 10^{-6}, 2 times 10^{-6}. How sensitive is the TSPA or your performance assessment, the TPA, to that difference?

MR. SHAH: PCSA.

MEMBER WEINER: You are just using the PCSA?

MR. NATARAJA: This is only preclosure.

MEMBER WEINER: You're not getting into anything. Well, then how sensitive is your performance assessment, your preclosure assessment to that difference between and 1 times 10^{-6} probability?

MR. NATARAJA: Do you want to take that?

MR. SHAH: It would depend on the design they have, but this is a mean value, mean value, the fragility curve, and mean seismic has occurred which will include consideration of uncertainty in developing the mean values.

I expect that that shouldn't make much difference in the design, but they shouldn't design something that would be so close that you can just eliminate just because it's 1.6 or something. So I don't expect a big deal about it.

MR. STAMATAKOS: This is John Stamatakos. It really depends a lot on the slopes of the fragility curve and the slope of the hazard curve. If the slopes are steep, then that difference is low, if the slopes become very shallow, then those differences might emerge to be a little more significant. But we see all the final information, we won't know. But my -- I think my preliminary view is that those will not be significant.

MEMBER WEINER: Thank you. That was actually my question. So you are still, if I understand you correctly, you're still waiting to see all of the analyses to check on the sensitivity --

MR. STAMATAKOS: That's right. We don't have a final hazard yet for the service facility, so we don't know what that hazard curve looks like and what its slope looks like.

MEMBER WEINER: Thank you.

MEMBER HINZE: Dr. Clarke?

MEMBER CLARKE: No questions.

MEMBER HINZE: Andy?

VICE CHAIRMAN CROFF: I'll take basically a background question going to the second to last bullet there in your summary slide, and that was -- part of the problem was I didn't have time to finish my homework, I'll say, is that how were the industry comments on ISG-01 resolved as far as the proposed standard, the intra-staff guidance being a more conservative approach won't have been used previously?

MR. NATARAJA: We had discussions with the people who commented on it, but you might want to --

MR. SHAH: We had two meetings with representatives from NEI and EPRI.

MR. MURPHY: I understand that.

MR. SHAH: On this issue, and unless you have the design, it's all conjecture as to opinions are based on, not facts, but just assumptions that designs will be big. There was no concrete proof or evidence showing that it is conservative and it depends on how DOE decides to approach that. If they use the highest level of -- like 10^{-6} for your earthquake to design everything, then it may be conservative. But they don't have to. You have to consider the hazard curve and then involved with the fragility curve.

MR. MURPHY: Right, okay.

MR. SHAH: It depends on the approach they use, but based on the version 5 of the technical report, it seemed like they are on the right path. It's consistent with what ISG-01 requires and we do not expect that designs will be conservative. It will be consistent with storage facility.

MR. MURPHY: Okay, that's fine, but then actually the final answer would then depend upon the fragility of the facility as it's finally designed.

MR. SHAH: Right.

MR. MURPHY: And it might become, forgive me, an open question at that time?

MR. SHAH: I think they can probably

choose an approach which makes more sense from practical aspects and time consumption and whether it makes a difference in terms of financial burden and all that, it's a combination of a number of things. So they might choose something to make it faster or make it cheaper. I don't know. It's hard to say.

MR. MURPHY: Okay, so that's a question that may come up later.

MR. SHAH: But the biggest problem was nobody really understood how to demonstrate compliance. I think now both parties interpreting, NRC and DOE, they need to understand how to demonstrate compliance for the requirements which is where we are today.

MR. MURPHY: Thank you.

MEMBER HINZE: Dr. Reiter?

MR. REITER: Yes, I just want to follow up on a question on the issue of risk-informed and I'm learning a lot here because there are nuances here that I didn't pick up before. So after you do the screening criteria of -- is it less than 10^{-6}, and then you find that's great and you want to do a dose calculation, is that a completely deter -- this is where I want to make sure I understand. Is that a completely deterministic dose calculation?

MR. NATARAJA: Dose calculations, there is an acceptable methodology for -- depending upon the atmospheric conditions and the source term and the distance and all that. You have an acceptance methodology for calculating dose at a distance. That's what we're going to use. If you want to call it deterministic, I don't know. There might be probabilistic inputs that go into that in terms of -- I have no idea.

MR. REITER: That's what I wanted -- for instance, you could have one event having resulted in different damage states and those damage states could result in different doses. So those -- if it's completely damaged --

MR. NATARAJA: It's not going to be a calculation of one number. I think they will have to calculate ranges based on --

MR. REITER: I think there has to be some probability involved in that. It's hard for me to image that it's purely not probabilistic.

MR. NATARAJA: We have some kind of agreement about how to do dose calculations for both Category 1 and Category 2. Category 2 is essentially similar to what is done in outlines. Category 1 is a little more complicated because of whether you want a probability rate, the individual components and all that. But we have some agreement on that. I don't think that is going to be a big problem except I think DOE does not prefer to do dose calculations for some reason. They don't want to -- they want to show compliance by design alone, rather than getting to it because of some other complications about source terms and other things which somebody else might want to add perhaps.

MR. HILL: Britt Hill, NRC staff. The Department has the flexibility in its preclosure safety assessment to use whatever method it chooses so long as that method accounts appropriately for the uncertainty in the values they're using in the dose calculation. We do not require a probabilistic safety assessment for the preclosure safety analysis, but the DOE could use probabilistic methods to address the uncertainties inherent in the fragility numbers or other such numbers in the dose calculation.

Alternatively, the Department could use single values if the Department demonstrated that those single values appropriately represented the uncertainty in the available knowledge. So just to make it clear, we do not require in preclosure a probabilistic-based safety assessment. In postclosure, it is a requirement.

MR. SHAH: There is a guideline which supplements YNRPRSG-3 which talks about preclosure safety analysis with dose calculations, methods --

MR. REITER: Are those dose calculations not probabilistic?

MR. SHAH: I think like Britt said, DOE has the option to use probabilistic methods.

MR. NATARAJA: But the final comparison is going to be one number. Whatever that number is a defensible number that they come up with, has to be less than five rems, if they choose to use consequence analysis as a mode of demonstration of compliance. If they cannot do it by design or elimination of --

MR. REITER: Post-closure you have one number also, like 15 millirem, but that's not probabilistic.

MR. NATARAJA: I didn't get your question.

MR. SHAH: This one is not weighted by probability. Is that what you mean?

MR. REITER: Yes. I just want to make sure that whatever the answer is, this prescription is not yet written and that people can do various things as long as Britt says they satisfy this ability to deal with uncertainty. So they could do a probabilistic evaluation of the dose.

MR. SHAH: But for a single Category 2 event sequence, not combining with --

MR. NATARAJA: Individual event sequence.

MR. SHAH: Individual event sequence.

MR. NATARAJA: If that is going to happen and if there is a failure and if there's a consequence, that consequence has to be less than five rems to the hypothetical individual. That's it. Then you look at another event sequence. You're not adding this to something else.

MR. REITER: So, in single event sequence that's like just the crane falls. Does not take into account whether or not the walls fall or whether or not -- breaks. The demonstration of dose has to be on the single event sequence. Okay.

MR. SHAH: Sequence.

MR. REITER: Sequence, but you're allowed to rule out the single-event sequence if it's less than

-- the combined sequence is less than 10^{-6}. But the dose calculation is based on the single event sequence.

MR. SHAH: Single event sequent.

MR. REITER: Very good. thank you.

MEMBER HINZE: Neil, did you have a question?

MR. COLEMAN: Neil Coleman, ACNM&W staff. DOE has made a huge change in their program that affects the preclosure. They've introduced the TAD which his a standardized Transportation and Aging container. Most of the scenarios I can envision accident sequences would occur during fuel transfer where you could get a significant release of material, something would happen when the fuel was exposed. But with the TAD, there would be virtually no handling of spent fuel at the site. So rather than discuss all these generalities, what's one example of a scenario with the TAD where there could be a significant release that you've thought about?

MR. SHAH: For the spent nuclear fuel which will be handled using TAD, it's about 90 percent, not 100 percent. Ten percent -- that's the assumption DOE has made.

You could still, there would be a transfer facility, a fuel transfer facility, waste transfer, waste handling facility called WHF, where the fuel is transferred from these casks which are already in storage in other types of casks, not TAD. There would be a fuel transfer taking place, so there will be risks.

Also, during the handling of this TAD canister there's a potential for a drop which they left to account for, there could be fuel, a radioactivity release during the handling accidents.

To PCSA could be fairly simple. As you are saying the -- it could be fairly straight forward and simple and they could demonstrate perhaps, most of the time that -- again, we are not doing the PCSA, we're only reviewing it.

MR. SHAH: But still there is a 10 percent to 30 percent fuel that will be handled and transferred in a pool from these casks which are already in storage to the TAD cans.

MR. COLEMAN: So your sense is that the risk in your mind may be dominated by that small amount of fuel that could be handled at the site.

MEMBER HINZE: Thank you very much, Raj. We have allowed this discussion to go on because we do have some elasticity in the schedule. As I understand it, Mike, we do not have a formal presentation on the ASCE standard. So we have some flexibility.

With that in mind, what I would like to suggest is that we break at this point, if that's acceptable with you, and we'll come back and we will have Mahendra and then John Stamatakos and then an open session where we can have comments from the floor.

With that, let's take a 15-minute break and we'll return at 10:30. Thank you.

(Off the record.)

MEMBER HINZE: Our next speaker is Mahendra Shah. Dr. Shah is the senior-level adviser in the Technical Review Directorate of the Division of High-Level Waste. In that capacity, he advises the Deputy Director on engineering issues of the high-level waste repository.

Mahendra joined the NRC in 1999 and formerly was in the Spent Fuel Project Office. And prior to joining the NRC, Mahendra had more than 25 years of engineering, industrial experience in technical areas and management of technical programs. He holds a Ph.D. in structural engineering.

And we are very pleased to learn more about the interim staff guidance. And I'm sure that we will be hearing some of the same words we heard last November.

Thank you very much, Mahendra.

DR. SHAH: Thank you, Dr Hinze.

6) INTERIM STAFF GUIDANCE,

"REVIEW METHODOLOGY FOR SEISMICALLY INITIATED EVENT SEQUENCES" - DHLWRS-ISG-01

DR. SHAH: The purpose of my presentation is to discuss the key aspects of the interim staff guidance ISG-01, which was issued in September 29th, 2006. And, as Raj mentioned earlier, this supplements the economic review plan, revision 2 of 2003 because there were no specific detailed procedures to how one could comply with the requirements of the pre-closure safety analysis for a seismic hazard. That was the reason this was issued. And we gave the background for a need for that.

I am also going to discuss some of the things Raj already touched on, compare the methodology to describe NRC to seismic requirements for other nuclear facilities so that we can provide the background to people and they look at part 63 in context of the other parts.

The scope of the ISG is limited to review methodology for staff for seismically initiated event sequences within the pre-closure safety analysis. Pre-closure safety analysis is a systematic examination of the site for the design and the potential hazard which could occur, the event sequences, and the potential radiological consequences.

So that is a key aspect of the whole process, that safety analysis would identify structures, systems, and components which are important to safety. These are the components which are required to mitigate or prevent these event sequence from occurring, which would exceed the performance objective which was mentioned earlier, at the site boundary.

And here also are described category I and category II event sequences that depending on the likelihood of occurrence, which is only 10,000 during the pre-closure period, which could vary from 50 to 100 years. As mentioned earlier, currently DOE is using 50 years as the pre-closure period. And that's why it was 2 times 10^{-6}.

So PCSA is a top-down, holistic approach looking at the overall picture of what are the things which can contribute to release of radioactivity and what needs to be done to protect and satisfy the regulations. So it starts from identification of hazard, as mentioned, and concluding with the identification of safety SSCs.

Now, these are the process for the design and review to determine compliance, a method. I think one thing I would like to make clear, this is a staff-suggested method which staff will use to review. DOE has the flexibility to use any other process as long as they demonstrate compliance.

I think one way they were doing -- and we had interface with them, and we felt that they did not really demonstrate compliance. So this is what can be used if they want to. Unless they have some alternate method, they can use that, too.

The key aspect of this is and the key objective of this process is determining what is the probability of occurrence of an event sequence because then you can determine whether it is a category 2 event sequence or if it is beyond category 2.

If it is beyond category 2 event sequence, then you can eliminate from consideration a likelihood or from the hazards point of view. But if it is a category 2 event sequence, which is likely to occur more than one you can have during the pre-closure period, you can also consider the dose consequences. That's another way the requirements of part 63 can be satisfied.

And the key part of determining the probability of occurrence of an event sequence is this process here, where the fragility curves of this SSC is important to safety and event sequence are combined or convolved with the hazard curve. And this is a part which is a key element of this process. And that is what we are using. The ASCE 43-05 is the process to calculate that.

So this is the only part which we are taking from SSC 45 similar to the SSC 4305 methodology, which was mentioned earlier. So that is the extent to which SSC 4305 is used in this methodology. And I think John will discuss that these are the precedent in the MOX facility. John will talk about that to what extent it was used there. This is the main crux of the whole ISG in very short.

One point here. From a preliminary design, if DOE or we or the staff find out that making some conservative assumptions about fragility, you find out that the category of event sequence could be category 2, you can then refine your calculations and consider appropriately the failure definition as far as the fragility curves are concerned in order to reevaluate and then demonstrate that it can be beyond category 2. So the process is an iterative from our point of view as well as the design point of view, which DOE could use. So it is an iterative process.

This provides a comparison of the seismic design process. The main thing I would like to point out is and, as I said earlier, the part 50, 52, and 72 are a deterministic design process based on individual SSCs design.

Part 63 is a probabilistic approach based on individual event sequences, which could have more than one component. And probability of failure will enter into this probability of event sequences. So that is the main difference I would like to point out here.

Other differences are we do not have the design basis earthquake specified. Then can choose any design basis earthquake and the design criteria to design that. And this is the iterative process which I mentioned earlier. They have to design it, a certain preliminary design, and then look at the safety analysis, to what extent it satisfies the regulation, and then revise the design as necessary.

So this is the iterative part of the design, which literally has to be implemented during the design. And that's the thinking I mentioned earlier. Right now they use the design basis, as Rod mentioned, same as the facility for part 72.

As far as compliant with regulations, as long as they can demonstrate compliance with this category 2 event sequence, at least not exceeding 5 rem, or show that all the event sequences are beyond category 2. Those are the two aspects I wanted to talk about.

To summarize, the entering staff guidance provides the staff guidance for the review of seismic event initial event sequences. And it is not mandatory for DOE to use, like any other guidances, like YMRP.

The ISG methodology is similar to the one outlined in industry, contains some standard. And the similarity is in that process of calculating the probability of unacceptable performance or failure and the probability of occurrence of an event sequence.

As I said earlier, part 63 does not prescribe any design requirements, just the demonstration of performance of SSCs within the PSCA sequences. And, as I mentioned earlier, it is for a single event sequence for your safety analysis. You don't have to combine with all other event sequences.

That is the end of my prepared remarks. I will be glad to answer any questions.

MEMBER HINZE: Thank you very much, Mahendra.

Allen? Dr. Ryan?

CHAIRMAN RYAN: No, no additional comments. Thanks.

MEMBER WEINER: This may seem an odd question, but this is certainly not the first time that we have had a facility that has handled a lot of irradiated nuclear fuel. And I just wondered to what extent your review of the post-closure design has taken advantage of facilities like those at Hanford, at Savannah River that have handled a lot of spent fuel over the years and certainly had some seismic design issues.

DR. SHAH: I understand your question. Pre-closure, right?

MEMBER WEINER: Yes, during pre-closure. I mean, these were operating facilities. So that you would have the same general type of problems of seismic issues that you have with the pre-closure facilities at Yucca Mountain. Has there been any insert from the experience of those facilities?

DR. SHAH: We are going to a facility in November. We are going to Idaho facility. In fact, I am flying this afternoon. So we have about ten people there already to look at the operations and the risks involved, what are the potential hazards during the operations, and the designs of the facilities, what seismic levels they have.

So we are trying to keep ourselves informed so that when a licensed application comes, we will be able to make decisions based on the experience in industry.

DR. STAMATAKOS: Can I add? This is John Stamatakos.

I think the uniqueness of 63 requires that the compliance part is certainly different than for those other facilities, but we are going to leverage that way, I'm sure, all the experience we have on the capacity side and the engineering side to help us in the determinations of these fragilities and how these other systems tick.

So certainly a lot of the engineering experience is going to get drawn into our analysis. It's just that the ultimate regulatory requirement is different here. It is unique and compared to all of those other facilities.

MEMBER WEINER: Thank you.

My other question is, I am just a little bit puzzled by the use of the 10,000-year time frame for category 2 events when the longest time that I have heard for the pre-closure period is 300 years. Why are you using 10,000?

DR. SHAH: We aren't using 10,000.

MEMBER WEINER: Well, your probability of a --

DR. SHAH: The one in 10,000.

MEMBER WEINER: The one in 10,000 occurs one in 10,000 years, one in 10,000. Let me rephrase the question, then. Is there any account taken of the fact that the longest time that he pre-closure facility would be operating would be about 300 years?

MR. NATARAJA: It is even less. We are only talking about 100 years.

MEMBER WEINER: Well, that begs the question the other way. The FEIS certainly has several options that would stay open for 300 years. So are you taking that into account or does it make any difference?

MR. NATARAJA: No. Staying open doesn't necessarily mean there is going to be activity in current operations. So staying open means you just observe. It's a passive facility. There is nothing really pertinent.

MEMBER WEINER: So you are assuming operations for 100 years.

MR. NATARAJA: Right.

MEMBER WEINER: Thank you.

DR. SHAH: Which could be less than 100.

MEMBER HINZE: Dr. Clarke?

MEMBER CLARKE: No questions. Thank you.

MEMBER HINZE: Dr. Murphy?

DR. MURPHY: Just a simple question. Back to your comparison slide, please, Mahendra. I just now got the impression that you were concentrating a bit on the part 63 being an interactive process. I am going to presume that, actually, you are not anticipating that you will be iterating on, I'll say, your first block, that DOE will have made a set of chalcedonies and gone directly to their criteria and, in fact, won't be coming in here numerous times to get to the performance.

DR. SHAH: I am glad you asked that question. When we get the license application, DOE would have gone through this iterative process. So we do not go through that.

We will have the designs, which will be demonstrating compliance, either through the dose calculations or the calculations for the probability of event sequences.

As independent verification, we will do some checks. And the ones which are very close to 2 -- of course, we will be risk-informed in our review.

The ones which are very close to category 2 event sequence probability of occurrence will be examining those very carefully to make sure that their conclusions are reasonable.

DR. MURPHY: Okay. So, then, going back, the true point of this slide is that they're going to have an immediate performance objective, rather than --

DR. SHAH: Rather than the design standards.

DR. MURPHY: Standards. Okay. Thank you.

MEMBER HINZE: Dr. Reiter?

DR. REITER: Yes. Just to follow up on what Dr. Weiner said, if the repository remains open for 300 years, would that change, then, your performance, the probability performance?

DR. SHAH: I think, as Raj mentioned, it is the pre-closure operation period, which is what you have to consider.

DR. REITER: But you don't close it. It is still pre-closure.

MR. NATARAJA: If you are not having any active operations --

DR. REITER: It just stays there?

MR. NATARAJA: Yes. It is a passive

facility which is going to be observed. And variation safety has to be maintained. But there is no demonstration of another design which shows that category 2 event sequence is going to result in because everything is underground now.

DR. REITER: Right.

MR. NATARAJA: It's not in -- such facilities are all decommissioned hopefully. I mean, maybe there are some minimum facilities perhaps but no risk there.

DR. REITER: Okay. So that is not post-closure, and it is not pre-closure?

MR. NATARAJA: It is. Until permanent closure, it is pre-closure. But the design requirements and the performance demonstration is for the period during which you have got active emplacements --

DR. REITER: Okay. So you need active operations. Okay. Okay.

Just one last thing on the plot. I just want to make sure. When you do the convolution, you do single SSC, right, either a wall or --

DR. SHAH: Not necessarily. You can combine --

DR. REITER: Well, first you do -- I

remember the --

DR. SHAH: First you do, yes.

DR. REITER: Right. And then you compare it. Then you do multiple. Okay. And if that doesn't work, you look at dose. When you look at dose, do you look at multiple SSCs or you consider only a single SSC or just assume it fails and the stuff goes out?

DR. SHAH: They both fail because if your probability of event sequence is more than 10^{-6}.

DR. REITER: Okay. So they both fail.

DR. SHAH: Dose calculations.

DR. REITER: And that is not handled. The probability of failure doesn't count as long as it's just beyond a certain amount.

DR. SHAH: Right.

DR. REITER: Thank you.

MEMBER HINZE: Latif, you had a question?

DR. HAMDAN: Yes, I do. In the event sequence, you don't haver a unique sequence for each category, do you? One unique event sequence, once the seismic event occurs, you have one sequence or many?

DR. SHAH: There will be other sequences.

DR. HAMDAN: There can be more than one, right?

DR. SHAH: Yes, there could be more than

one.

DR. HAMDAN: And how do you assign weights as to how much weight you give each sequence?

DR. SHAH: Weight is not assigned in pre-closure safety analysis. Event sequence is what you consider. It's very clear.

DR. HAMDAN: So when you have a seismic event, you have one unique event sequence with one dose?

DR. SHAH: Yes. That's where the differences are between.

DR. HAMDAN: So one sequence, one dose for each category? There are variables, aren't there?

DR. SHAH: I beg your pardon?

DR. HAMDAN: There can be variables. I mean, there can be some seismic events that exceed the 10^{-4}, you know, putting them in different sequences. I mean --

DR. SHAH: You could have more than one sequence for category 2 if that is a design approach taken, but you have to consider if you are using the dose as a criterion, calculating the consequence, you have to calculate for each individual event sequence. We will not add them.

DR. HAMDAN: Yes. I understand. But is

there one or more than one event sequence for each?

DR. SHAH: There could be more.

DR. HAMDAN: There could be more?

DR. SHAH: Yes, there would be many more.

DR. HAMDAN: And there is more. Then what do you do? How do you go about deciding which dose, which event sequence and which dose, you know --

DR. SHAH: That would be part of the pre-closure safety analysis, which they will be valued how to eliminate some and how to consider some. So they could make the SSC stronger so that that event sequence will not occur, which will lead to radioactivity more than five.

But there could be some other ones which could be at a single event sequence less than five rem. So they can say that it doesn't matter if those components fail. So that's where the risk-informing and the performance-based comes into the picture.

DR. HAMDAN: It's clear that if you are within -- safety events, then you are okay. But once the design is decided and you have an event that will exceed the design and you end up with more than one event sequence and more than one dose, what do you do then?

MR. NATARAJA: For each event sequence,

you have to compare and show it is less than five rem.

DR. HAMDAN: Each event sequence.

MR. NATARAJA: So there is only one that exceeds the dose, the standard, then that event sequence needs to be further examined to either do something to the design or whatever can be done.

DR. HAMDAN: So one evaluation will lead to reevaluation or --

MR. NATARAJA: That is part of PCSA. That is we will be looking at some of those things. They have books and books of calculations.

DR. HAMDAN: Right.

MR. NATARAJA: But what we will find in the license application will be a final iteration of all those. You will not find all the eliminated event sequences. You might find them in some reference. We will have to go and review them if necessary to see how they eliminated some of those event sequences.

DR. HAMDAN: I see.

MEMBER HINZE: Let me ask a follow-up question to Latif's, if I may. And that is a question that has been raised by EPRI concerning the number of convolutions of fragility and hazard curves that need to be made. Do these need to be made for all SSCs, which might involve tens of thousands of convolutions?

Would you care to respond to that?

DR. SHAH: You mean this process as to be --

MEMBER HINZE: Right. How do you --

DR. SHAH: It would be based on the PCSA. They are able to identify those components which are important to safety. You are going from top down, not bottom up.

You don't start with all SSCs convolving. So you determine which are the components which are important to safety that DOE decides to designate, like crane. They can say, "I'm going to design it so there will not be any failure of crane." And that's when it stops.

Now, operational, there are human errors which could lead to some failures of the crane, just drop of a cask. That is something that devalues. But now you do seismic.

So they can decide that "I am going to make the first component strong enough so I don't worry about the other components. So it's an approach that I can take.

MEMBER HINZE: Will part of the SER be evaluating the importance of the safety items that have been specified by DOE, then?

DR. SHAH: Yes, exactly.

MEMBER HINZE: Right. And that will then minimize the convolutions and limit this to those that DOE and you have accepted as important to safety.

DR. SHAH: We will also review how they came up with those components, --

MEMBER HINZE: Sure, sure.

DR. SHAH: -- their logic and their rationale.

MEMBER HINZE: I think that is important to get on the table.

Any other questions or comments?

DR. HAMDAN: I just have one follow-up on that, Raj. How does DOE or in your review methodology on ISG, how do you decide that yes, DOE has exhausted all event sequences that could occur?

DR. SHAH: That's what we will be reviewing. We will be reviewing their design to make sure or verify that they have considered all the potential event sequences. That's why we have actually worked on a lot of operating experience. We have a report which we are working on which is being issued. We look at what are the potential event sequences that could occur due to operational type errors.

DR. HAMDAN: That's based on experience.

DR. SHAH: Based on the industry experience. And that's why I mentioned that we are also visiting a lot of sites in the operation.

DR. HAMDAN: Yes. Thank you.

MEMBER HINZE: With that, then, I would like to thank Raj and Mahendra for their presentations and being involved in this discussion. I hope that you will be able to be around for the rest of the working group meeting in case any further comments come up.

With that, we will move to our next and final speaker of the working group, Dr. John Stamatakos. John is currently in his new position as the Assistant Director of the Washington office of the Center for Nuclear Waste Regulatory Analysis.

John has a Ph.D. in geophysics and has been involved in many aspects of the Yucca Mountain studies but more recently has been involved in evaluation of the seismic hazard at various nuclear facilities. And one of those is the mixed oxide fuel facility at the Savannah River site.

This is our chance to learn something about the application of the ASCE standard. And, John, if we could ask you if you could provide any guidance to the Committee on aspects of this standard, this consensus standard?

We don't have a speaker to discuss that specifically with us. So anything you can add? We will be happy to give you some extra time. I know you would be happy to do that.

DR. STAMATAKOS: Thank you.

CURRENT SEISMIC DESIGN REQuIREMENTS

FOR MOX FACILITIES

DR. STAMATAKOS: This was not necessarily that recent an analysis of MOX. We actually began this, what I will talk about, back in 2002, when the original construction authorization request was submitted and worked for the NRC began and our initial review.

So what I will do with this presentation first is quickly summarize what we did and the evaluation of that particular facility in terms of the construction operation request and the seismic aspects of the review and then just briefly talk about the application of the ASCE standard and maybe just use the extra time to entertain some questions that you might have about how it particularly was applied and used in this instance.

So in 2002, what was at that time Duke,

Cogema, Stone and Webster as the applicant submitted the construction authorization request. And we began our review.

In 2006, there was a change in the corporate name. And now the applicant is referred to as Shaw Areva MOX Services or just MOX Services is what I will refer to them in the rest of this presentation.

The evaluation of the construction authorization license application was conducted under NCFR part 70 using review guidance laid out in NUREG-1718, which is the standard review plan for application of mixed oxide fuel facility.

It is a risk-informed and performance-based regulation, although I will defer to Allen that it's risk-informed in a very graded sense. It's not a full risk-informed application, as he alluded to in his question, I think, a little while ago.

It does require the application of integrated safety analysis, which is ongoing now in the receipt and possess part of the application. And it includes a baseline design criteria and defense-in-depth as specified in 10 CFR part 70.64(a) and (b). And these are stated in sort of broad performance-based languages, for example, adequate protection. So it's a little less proscriptive and a different approach than what is done in part 63.

Now, in this construction authorization request, what MOX initially proposed to do was to use the same seismic design basis as nearly plant Vogtle Nuclear Power Plant, which is within a few tenths of miles from the facility at Savannah River. And Vogtle was licensed using the old 1.60 reg guide, 1.60 spectrum. It's the NUMARC spectrum scale to a peak ground acceleration of .20 g.

And the target was in using this particular spectrum, it's not a uniform hazard spectrum. But the target was to roughly have about a 10,000-year return period exceeding probability for the ground motion parts of the spectrum that are probably at the structural frequency of interest somewhere between 1 and 20 hertz.

During the review, after some discussions, we came to agreement that the vertical spectrum would be also the same based on the same 1.60, scaled to .2 g. And a separate sole stability analysis was done. MOX used a 2,000-year ground motion scale through the soil. The input motions in their sole stability analysis add up to .20 g peak ground motion.

Now, an important part of the selection of this particular design basis that MOX was to then show how the design spectrum compared to other seismic criteria, both DOE and NRC, for the site.

So MOX established a Savannah River site-wide design basis earthquake, implementing DOE standards, DOE standard 1023, which is a method that parallels 1.165. And, in particular, DOE used their performance categories as defined in DOE standard 1020, which is where the risk grade comes in.

And DOE standard 1020, DOE specifies a number of performance categories. And the highest performance categories are PC3 and PC4, which are roughly the 2,000-year and now the 2,500-year earthquake and the 10,000-year earthquake.

And these would be for facilities, PC4 facility. The highest grade would be for a DOE-licensed nuclear power plant, 2,000 or 2,500-year facility would be for a fuel source facility or other kind of fuel-handling facility.

So DOE had these performance categories based on this risk-graded approach. And they had design spectra earthquake that they could compare against what they were proposing for this facility. And I will show you examples of those comparisons in a subsequent slide.

I will point out that what MOX relied on were the old Lawrence Livermore and Electric Power Research Institute seismic hazard studies, which were conducted in the 1990s, as a basis for their PC3 and PC4 hazards.

The other aspect of their comparison was to do what DOE calls an historic check. They wanted to compare their design spectra against a large, the repeat of a large, historic earthquake. And in this part of the world, a large earthquake of interest was the 1886 Charleston earthquake, which is interpreted as having a magnitude of about 7.3 maximum modified Mercali of either 9 or 10, at a distance of about 120 kilometers from the site.

So the map on the right shows a distribution of initial shock, which is a star of the Charleston earthquake, the Mercali zones site. You can see the Savannah River site, the location of plant Vogtle, and then some modern seismicity just plotted as red dots overlaid on the map.

Here is the crux of the comparisons of the various earthquake spectra. The design spectra that they chose are the orange or yellow stars. So this is the reg guide 1.60 spectra anchored at .20 g.

The red, the two red square, and the red dot spectrum are the bedrock PC3 and PC4 based on the EPRI and Lawrence Livermore studies. The corresponding soils, PC3 and PC4, for the site are shown in the green dots and green squares. These correspond to the 2,000 and 10,000-year hazard spectra.

And then what was estimated by repeat of the Charleston earthquake is shown as the purple triangles. And so you can see that where their design spectra falls between the PC3 and PC4 surface hazard spectra and envelopes the historic check.

And so all of this was done to provide some reasonable assurance that they had a robust design spectra that would be able to maintain safety of the facilities.

In our review, we asked MOX Services to do one additional step. Because we wanted to understand performance, we asked them to do some probabilistic performance evaluation

bolster all of the design information to try to bolster all of the design information.

And so in response to the RAI, MOX Services did an analysis where they looked at about half a dozen of the important systems, structures, and components, important to safety, and use that design spectra and hazard spectra, actually, for the site to demonstrate how well these selected SSCs were performed.

And, in fact, all of the ones that they tested showed that they would maintain their intended safety functions at failure probabilities of 10^{-5} or less. And so that we felt was consistent with the guidance we had in NUREG-1718 for the performance of the facility.

And what became the methodology in ASCE 4305 was used to calculate these individual failure probabilities. So this is where the precedent that we cite in the ISG comes into played. We saw that in this license facility.

The applicant was able to demonstrate failure probabilities using the convolved hazard and fragilities. And the fragilities that were calculated were calculated based on the methods that were described in 43-05. That's all we intended by the connection to the ASCE standard.

So, in summary of our evaluation, we found that the application of the hazards that they used for the bedrock was appropriate; the soil response was appropriate; and that their design, their proposed design, in concert with their performance evaluations was sufficient to give us assurance that the facility would be able to maintain its safety functions, at least in terms of the construction authorization, until what's ongoing now in the receipt and possess, where they are doing the full spectrum of safety.

So that is the end of my prepared slides on what we did for MOX. And I would be glad to use this time to talk a little bit more about the ASCE 4305, but go back to the point that it's a pretty simple, in our view it's a pretty simple, application of this standard as a methodology that allows someone to calculate fragility convolved with hazard and estimate failure probabilities of important systems, structures, and components.

And those then become, as highlighted in Mahendra's talk, components of the safety of the pre-closure safety system.

MEMBER HINZE: John, if you would like to expand on any aspect of the civil engineering standard, we would appreciate it.

DR. STAMATAKOS: Well, I don't know, in particular, what other questions you might have about how that is applied. You know, as I said, I think the critical aspect of it is in the alternative methods that it provides for calculating fragility. So either based on the high conference, low probability method or other methods, Mahendra can probably speak to those better than I can.

That is one of the aspects that we saw as precedence that we could cite, that, rather than having to have full data to calculate some of these fragilities, that you could assume a shape for the fragility curve and anchor it somehow on some known value, as described in the ASCE.

MEMBER HINZE: Well, I don't know that it's an integral part of the 4305, but did you have any problems or did you see any concerns regarding determining what was important to safety and which of the then developed fragility curves and --

DR. STAMATAKOS: I don't think what you determined and I don't think the standard itself gives you the specific guidance on how you determine which SSCs are important to safety. I mean, as Mahendra pointed out, the --

MEMBER HINZE: But did you have any problems in --

DR. STAMATAKOS: No, no. In this particular case, I mean, the analysis for the MOX facility, we weren't requiring the applicant to do that full kind of pre-closure safety analysis. The design, the basis for the license for the construction authorization, was based on their proposed design.

What gave us some confidence that that was an appropriate design was an analysis that showed that given that design, thee particular systems, structures, and components would perform very well.

MEMBER HINZE: How did you verify the fragility curves that they used?

DR. STAMATAKOS: In that analysis, our engineers just did a review of those, though it escapes me that going back to 2003, when we looked at this, I don't remember exactly what -- Asad Chowdry and his group at the center were the ones who looked at that particular structural analysis. That's as much as I can say about that without having to go back and look at that analysis in detail.

MEMBER HINZE: Did they actually calculate some of their own fragility curves?

DR. STAMATAKOS: I don't remember.

MEMBER HINZE: I'm going to pass it on to the Committee for further questions. Allen?

VICE CHAIRMAN CROFF: Thanks.

CHAIRMAN RYAN: I am good. Thanks.

MEMBER WEINER: I would ask you a similar question. I am surprised that they used Vogtle as a model, as a template, because there are reactors on the Savannah River site. Aren't they as seismically sensitive as the Vogtle plant would be? Wouldn't you use the same design, seismic design, criteria?

DR. STAMATAKOS: I think they felt that by using the Vogtle, which was an NRC-licensed facility, that this comes into the risk grade, that because the argument was that this was inherently a less risky facility than a nuclear power plant, that by using a nearby power plant design criteria, they were assuring some conservatism in their design and that would pass muster as a way to get this facility licensed.

MEMBER WEINER: Is NRC planning to look at all at the design criteria for the facility, for the reactors specifically, that are on the Savannah River site? Because you have reactors that were operating for several decades.

DR. STAMATAKOS: Go ahead. You can answer it.

DR. SHAH: I was going to say that we are going to Savannah River site also to look at their designs and also operational status.

MEMBER WEINER: Thanks.

MEMBER HINZE: Dr. Clarke?

MEMBER CLARKE: No questions.

MEMBER WEINER: Dr. Murphy?

DR. MURPHY: I have one request for the blind guys in the audience. If you could go back to your figure number -- the one with the MOX design and spectra on that? I'm going to ask you to point out the -- yes, there we go -- ask you to point out the various items that you've got on there.

DR. STAMATAKOS: Okay. So the --

DR. MURPHY: I guess starting from the top would probably be easiest.

DR. STAMATAKOS: The top is the 10,000-year. This is the PC4 soil spectra for the site. The stars, the next one, is the old NUMARC spectra, 160 anchored at .2 g.

The one underneath it, the red, is the 10,000-year bedrock hazard spectra. The one underneath it, this one right here, is the 2,000-year soil spectra.

DR. REITER: Where is that?

DR. STAMATAKOS: That is this one right here.

DR. REITER: Oh, there. Okay.

DR. STAMATAKOS: In the green. And the one underneath it, this small red one with just a few dots, is the 2,000-year bedrock spectra. And then the one with many points, the little triangles, this is what would be the response at the site given the repeat of the Charleston earthquake. So that's the historic check that DOE did or that MOX Services did for a repeat of the Charleston earthquake.

DR. MURPHY: Okay. I will say thank you on that and make a comment for your question that in my mind, one of the reasons they may have selected Vogtle, rather than one of the other Savannah River reactors, is that for Vogtle, both EPRI and Livermore did specific calculations for those sites and they would not have been available for the other Savannah River items.

DR. STAMATAKOS: Thank you. Thank you for that.

DR. MURPHY: Thank you.

MEMBER HINZE: In reference to Andy's first question, Mike Lee, do we have an electronic version of this spectra, of this figure? Do we have an electronic version --

MR. LEE: Yes.

MEMBER HINZE: -- so we can see that expand in color form?

MR. LEE: Yes, right.

MEMBER HINZE: And that will be in the transcript. So this will be available in little enlarged form.

MR. LEE: Isn't there a feature in PowerPoint that allows you to blow up or maybe I'm thinking of Adobe maybe. Yes. Okay.

MEMBER HINZE: But that is available?

MR. LEE: Yes.

MEMBER HINZE: Okay. Dr. Reiter?

DR. REITER: Yes, two questions. Just on this plot, you say "combined EPRI/Livermore." What does that mean?

DR. STAMATAKOS: The hazards aren't exactly the same because they use different definitions of sources in those. So basically equal weight as inputs into the hazard assessment, equal weight for what you would predict for EPRI and you would predict --

DR. REITER: Just look at EPRI versus Livermore itself. Is there a big difference?

DR. STAMATAKOS: There is not as big a difference here as there is in other parts of the country.

DR. REITER: And one more question. On slide number 3, you talked about you picked the

10,000-year spectrum. And then it says for source stability analysis, "MOX Services used the bedrock 5 times 10^{-4} ground motion scale." Why did you change the probability there?

DR. STAMATAKOS: Well, I didn't change it. That's what MOX Services did. And that was a separate calculation that they were doing for things like stability or liquefaction potential or they phrased it slightly different.

I am trying to remember. The reasons for that I think were the analysis codes that they were using to do those needed slightly different inputs, but I can't remember. You know, I have to go back to the detail.

DR. REITER: But it's not the --

DR. STAMATAKOS: It's not the same.

DR. REITER: Doesn't it apply lower risk or something? Because you're going from 10^{-4} to 5 times 10^{-4}.

DR. STAMATAKOS: Yes. I think that the way that they equated it was to try to modify that so that it was amplified through the soil that they were getting the same peak ground acceleration. So that's where that modified through the soil.

I have to stretch my memory to go back.

DR. REITER: Okay. That's all right.

DR. STAMATAKOS: I believe that that's what they did.

DR. REITER: Okay.

DR. STAMATAKOS: No. I think at the time we concluded that it was not something that was necessarily less of a risk. It was a different way to do that analysis.

MEMBER HINZE: Additional questions from the staff or the audience?

DR. HAMDAN: Just to John or everybody else?

MEMBER HINZE: To John for now.

DR. STAMATAKOS: Raj just pointed out I have an error on this slide, a decimal point. These I have off by a factor of ten.

MR. NATARAJA: I was wondering how you can --

DR. STAMATAKOS: Yes, very small hazard.

MR. NATARAJA: Yes. Why would you even bother doing it.

MR. COPPERSMITH: Bill, could I ask a quick question?

MEMBER HINZE: Please.

MR. COPPERSMITH: Kevin Coppersmith again.

John, I wanted to ask you -- I'm not a student of part 70, but I understand that in the old compliance demonstration or risk comparison, the 10^{-5} that was used comes from a definition that the applicant is allowed to make for the words "very unlikely," as I understand.

DR. STAMATAKOS: Or highly unlikely, right, for highly unlikely --

MR. COPPERSMITH: Highly unlikely.

DR. STAMATAKOS: -- high risk. That's right.

MR. COPPERSMITH: Did they justify that? That would be comparable, by the way, to our, if you could make an apples to oranges comparison to our, 1 in 10,000 in the pre-closure period for beyond Category 2 space for part 63.

In other words, we have been talking about 10^{-6} for an event sequence. Is that roughly comparable to this highly unlikely definition of 10^{-5}?

DR. STAMATAKOS: I think that the phrase that you used with me is apples and tangerines in the sense that this is such a different approach in part 63 to how we define and look at safety comparison to any of these other facilities. I don't think you can make that comparison.

MR. COPPERSMITH: Okay.

MEMBER HINZE: Thank you.

MR. CHERCHINSKY: Can I add something on highly unlikely?

CHAIRMAN RYAN: You need to identify yourself, who you are with.

MR. CHERCHINSKY: Sure. Okay. Dave Cherchinsky. I'm the MOX project manager at NMSS fuel cycle.

MOX Services' definition of highly unlikely is a little different. There are different approaches in part 70. There's a quantitative and a qualitative approach. They have chosen the qualitative approach of combining various factors to determine highly unlikely.

So if you read any of their documentation and see "highly unlikely," you really can't equate to a numerical analysis because they have done it a different way.

MEMBER HINZE: Thank you very much.

MR. CHERCHINSKY: You are welcome.

MEMBER HINZE: John, we thank you very much. At this point please stay where you are, gentlemen. But we now have an opportunity for the public or any organizations that have not been involved in the presentations to make statements.

Rod, if you would, please? I understand that you wish to come to the front and introduce yourself. And I believe you want a particular slide brought up.

MR. McCUOLLUM: Yes. Do I have to do it?

MEMBER HINZE: No. I think that someone could help you with that.

STAKEHOLDER AND PUBLIC COMMENTS

MR. McCUOLLUM: Yes. I am Rod McCuollum from the Nuclear Energy Institute. And the slide I would like to have in the background here is Mahendra Shah's slide 5. And I guess while that is coming up, I would like to thank, to begin here with both a thank you and an apology.

I cannot thank the Committee enough for the thorough look into this issue. I know this was an issue that we have been raising based on our experience at commercial nuclear plants and what we're seeing at Yucca Mountain.

The record that you folks are creating here is very important. We do intend on behalf of industry to participate in the Yucca Mountain licensing process. And this record will be very useful to us.

I think we are getting a lot of these issues out on the table. The thing I will apologize for is that I had hoped we would be able to participate a lot more actively in this. I mean, you folks went to all of the trouble to set this up.

And because of recent events in Japan, where there was a seismic event affecting a nuclear plant, the seismic experts that I might have at my disposal through EPRI are simply not available. Their time is more than 100 percent committed these days.

But what I would like to do today because this was I think such a thorough exploration of the topic, I am not an expert. I am not certainly myself a seismic expert. Although I have stayed in a Holiday Inn Express before, --

(Laughter.)

MR. McCUOLLUM: -- I am not going to pretend to be a seismic expert. But what I would like to do is try to convolve some of what I have heard here today with my own nuclear engineering sense of common sense, particularly as it comes to what is risk-informed regulation, and in a minute get back to a comment I think that was very prescient that Dr. Croff made earlier.

In this graphic here, Mahendra has shown the different regulatory processes we have. And I have heard apples and tangerines, apples and oranges. I might call it apples and bowling balls, with part 63 being the bowling ball.

These things are not the same. I think what we have heard is part 63 is uniquely different. And ISG-1 brings into that uniquely differently world of part 63 something that has really never been tried before.

There is a very important typographical error on this chart. Down under the part 63, you see 5 times 10^{-4} for year hazardous 5. And I think this has been said several times. It was not an intentional error. It's 10^{-4} in the life of the facility, which is approximately 100 years. And that takes you down to 10^{-6}.

So you're looking at a 10^{-6} earthquake, which is far beyond anything that is your -- and, again, DOE has choices. That is your starting point from which to choose. And that is far beyond anything that has been looked at in these other regulatory processes.

What that takes you to in Yucca Mountain is approximately a 3 g earthquake. You have heard talk about the .2 g earthquake for Vogtle. Power plants in California are designed to .6 g earthquakes. So you're looking at a starting point for the DOE analysis of an earthquake.

I envision almost a scenario where you have this cataclysmic event that shakes the planet apart. And the only thing floating intact in space would be the Yucca Mountain surface facilities. We have not been able to find anything designed to a 3 g earthquake.

So, getting back to is this risk-informed and a comment Dr. Croff made, you start with this 10^{-6} probability. You don't look at the consequences. You don't look at the whole risk equation.

And if we could basically go back to slide 4?

MS. KELTON: Just hit 4 and ENTER.

MR. McCUOLLUM: Hit 4 and ENTER? Wow. Okay. I'm an expert at something now.

What is happening is because the ISG-1 methodology and I think the presentation we just heard from John Stamatakos is important because what he told you was they applied this type of methodology as a confirmatory performance evaluation at the back end of the design process as an extra step to look into this. They did not attempt to do it for an entire facility at the very front end of design.

And that is why you have also heard a lot of talk about DOE simply choosing not to go the consequence route. That gets you back to designing a facility that will withstand a 3 g earthquake because what happens is as you get to this event sequence, less than 1 in 10,000 in 100 years or 10^{-6}. And you don't want to go down that route of convolving fragility curves and seismic curves for all of those components in the facilities.

I don't think DOE is going to go down that road. So you end up simply designing a facility that can withstand assuming things won't fail. You go down to the point of making sure you don't have the failure so you don't have to go through that iterative process. And you end up designing a facility to withstand a 3 g earthquake.

Now, a lot of this, we have said the proof is in the pudding. And some of the pudding is already out there. I mean, we are hearing that the Yucca Mountain surface facilities might have four-feet-thick concrete walls, as compared to reactor buildings, a much higher hazard.

You know, we were talking earlier about core damage probabilities. There is no core to damage here. There are fuel elements that if you drop them and break them and break the containers, then you might have to deal with the probability of a release.

But in terms of risk-informing it, there is no core damage frequency to look at here, period, anywhere on this site. You are looking at fuel-handling buildings that would be designed much more robustly than reactor buildings, again, .6 g earthquakes for reactor buildings in California versus 3 g earthquakes, simply because you don't want to go down this unprecedented convolution of all of these curves.

Basically if you'll start to convolve the curves, you find out where things intersect. You find out where your vulnerabilities are. You can iteratively do the whole design. That might take 100 years to do that, but you could do that. Instead, you cut it off with your 3 g earthquake. And then you are really being basically driven by the tails of the distribution is what is happening here.

Without speculating further on what DOE's surface facility design will be, whether they will be the last intact thing floating out in space when the Earth is destroyed, there is some absolute. And you are going to have later in your meeting, I think

Thursday, a representative from Holtec.

I have two versions of the TAD spec on my shelf in the office: the first draft of the TAD spec and then the final one that was issued after a couple of things happened. They got feedbacks from the vendors, and they incorporated the latest seismic find.

I think we got from Raj a very excellent description of the history they went through. And that history was happening contemporaneously to the design effort.

The specification for the first draft is about a quarter-inch thick. The TAD specification, final, is about two inches thick. The difference is the additional information in there that is needed to support the seismic analysis.

To answer the question very directly, is this the same as part 72 facility, the answer is absolutely not. The storage overpacks for the TAD on the Yucca Mountain site because of the seismic issue will be different from any storage overpacks ever designed and in a way that is on the more rigid side.

And I think if you would -- I don't know how much the Holtec representative will want to talk about his design when he is in the middle of a procurement, but I think that might be a valuable question to ask.

So I think the answer here is we are talking about apples and bowling balls. This is something that is very different. It is something that we are looking at taking a lower risk and designing against it at a much higher level at Yucca Mountain than anywhere else in part 50, part 72, part 52.

And why that concerns us as an industry and why this is certainly one of these issues we will want to weigh in on when we participate in the licensing process is because, as I think this Committee knows, all resources are finite. And resources spent towards risks that don't matter divert away from spending resources on things that do matter, not to mention the fact that these buildings will impose more construction risk because it's harder to build buildings with four-feet-thick walls and very thick roofs to go with them.

And, of course, the construction workers building the facilities will be employees of NEI's member companies. So we would be looking at that.

So I thank you for your time. And I encourage the Committee to continue to explore this issue. This is a very interesting and a very I think important issue. So thanks.

Any questions or --

DR. SHAH: May I respond to that?

MEMBER HINZE: Yes. In fact, I was about to invite both you and Raj to respond.

DR. SHAH: Can you go back to that slide --

MEMBER HINZE: And would you state --

MR. McCUOLLUM: Okay.

MEMBER HINZE: Rod, if you wouldn't mind, stay up. And perhaps we will have some commentary.

DR. SHAH: I would like to correct a misunderstanding Rod had. That is no typographical error. The design basis is 5 times 10^{-4} per year, which is a 2,000-year return per year. That is the design basis. It is not 5 times 10^{-6}.

And DOE has an option. They could design the facility for this and then do the convolution considering the fragility of components to show that event sequence is less than 10^{-6} per year or they could design a component, which is what they chose to do in an aging cask, which he mentioned, for 5 times 10^{-6} per year hazard level, which is their choice. They do not have to. And they said they will not tip over. To me that's a very, very, very absolutely conservative without thinking approach.

I am really appalled at what DOE has done there. And we did not have a chance to comment on that. It was not in the preliminary spec. And it just was issued as a final performance spec without any input from anybody.

So that was a wrong decision they made in my opinion. They could allow the cask, aging cask, to take over and show that the fragility of the release of radioactivity is very unlikely, even considering the -- I design casks for meeting part 72. If it tips over, nothing is going to happen. The standard design they have.

MR. NATARAJA: To add to that, some of the things that you are mentioning about TAD thickness and all of that comes from post-closure requirements, nothing to do with pre-closure.

MR. McCUOLLUM: Yes. I was only commenting --

MR. NATARAJA: People are really mixing up --

MR. McCUOLLUM: Yes. I was only commenting on the overpack in the seismic data, which is in the TAD spec. That seismic appendix to the TAD spec is --

MR. NATARAJA: Post-closure of seismic considerations, they have to go all the way to 10^{-8}. So there is a different requirement. And the way in which you do that is by showing what happens as a result of failure to the CCDF and the DSBH. It is not the same dose calculations of 500 and set the boundary and all of that. They are two different things.

So I think now, in addition to apples and -- what is it? -- bowling balls, we are now talking about apples and probably something else.

MEMBER HINZE: So those designs are driven by the strong motion, the tails on the

MR. NATARAJA: The seismic design does not --

MEMBER HINZE: No. The post-closure. In the post-closure.

MR. NATARAJA: Yes. But you don't design against it. You do the consequence analysis using some --

MEMBER HINZE: That's correct.

MR. NATARAJA: There is a big difference there.

MR. McCUOLLUM: I want to be perfectly clear. The information I was referring to in the TAD spec is driven entirely by the pre-closure aspects of the aging pad out there at Yucca Mountain. I certainly understand the post-closure design basis. I was at the post-closure seismicity meeting last week. And I understand that that is a whole different ball game. That is bowling balls and planets.

DR. SHAH: Design basis for the part 63, which DOE has chosen, appropriately, is the same as part 72 for any part 72 facility, 5 times 10^{-4} per year. And they could have done the same thing for aging casks except that they would have considered the consequence, which is a tip-over, to show that there is no consequence. They didn't have to design or this aging cask of 3 g. To me that is completely absurd.

MR. NATARAJA: And no surface facility buildings are designed to 3 g to the best --

DR. SHAH: No, they are not. They are designed to 5 times 10^{-4} per year hazard, all the other facilities. I think maybe a DOE person wants to add to that.

MR. McCUOLLUM: I would certainly welcome hearing from DOE.

MEMBER HINZE: Let's hear from John Stamatakos. And then we will ask for --

DR. STAMATAKOS: I just want to make a

couple of points. One is the 10^{-6} is not an impressive analysis. Certainly all the PRAs that were done used the full hazard curve to low probabilities for those facilities where PRA was done.

The IPEEE, some of those hazards also they evaluated low probability earthquakes in their analysis. The misconception in Rod's statement is design. And there is no requirement for design. All this ISG looked for is what is on performance. And there is a big, important distinction between design and performance.

I just want to make that exceedingly clear that that misconception that people have to design on some level is a false one.

MR. McCUOLLUM: I think where it connects in that if you have a choice, if you don't want to design the 10^{-6} -- and I really believe if -- I apologize if I was picking the wrong number here to look at, but we are looking at a 10^{-6} hazard here at Yucca Mountain.

You have a choice to go through the ISG-01 methodology on the front end of your design process and look at those entire curves and convolve them with those fragility curves for all the components and try to unwind all the interactions between those components or to take the approach that DOE is taking, which is to more simply design, simply design it so it can't fail.

We have seen that already in the TAD spec. And I know we heard it. I saw Andy Kadak in the back with his hand up. We heard definitely at the TRB meeting a few weeks ago that they are designing 2 or 3 g earthquake out there.

DR. SHAH: Just for aging casks, just for aging casks, which is a map and is the wrong approach.

MR. McCUOLLUM: I would submit that the ISG-01 methodology really leaves them with little choice.

DR. SHAH: It's not because ISG-01. It's their choice.

MEMBER HINZE: Andy, did you --

MR. KADAK: My name is Andy Kadak. I'm here as a U.S. Nuclear Waste board member but not speaking for the board, obviously.

This issue is a troubling one for me as well. You know, when you start multiplying numbers, you get to low numbers. Now, whether or not DOE decides to design to 3 g or some other lower number with fragility curves, you are right. I think that is their call.

My question is this. When part 63 was originally written, was it the intent of whoever wrote it to design the surface facilities to the same probabilistic degree than the subsurface facilities?

To me we are getting confused because in my past life as a Yankee Atomic person, we had things such as single failure-proof cranes. In PRA space, there is no such thing as a single failure-proof crane. There is some finite probability. And if you start multiplying small numbers by small things, you will get a big number in terms of a potential consequence.

So I am just raising the question in terms of the framers of the regulation that I suspect it wasn't their intent to design surface facilities for a 100-year life -- I think that's where you were going, Ruth, in your question -- to the same rigor, especially given the hazard that a subsurface facility that is supposed to operate for hundreds of thousands of years is.

So I am not sure who has looked at that in depth to see whether or not it should be different, but if it were designed like a surface facility at a nuclear power installation or some other place, I think all of these discussions would be greatly simplified and we might be able to use the old MOX approach to reg guide 160 and NUREG-800, which would make it very clear what you have to do and is consistent with common practice for fuel-handling facilities.

Now, I will be prepared to be educated, but that is my comment.

MR. McCUOLLUM: Andy has reminded me there was one thing I forgot to mention with regards to the intention of the regulation in terms of we are following a process here that is definitely different than the other processes and may not be risk-informed when one looks at the hazard.

63.102(f). I was going to do this, and I forgot to do that when I was speaking. It states in 63.102(f), "The pre-closure safety analysis is a systematic examination of the site, the design, the potential hazards, initiating events, and the resulting event sequences and potential radiological exposures to workers, the public. Initiating events are to be considered for inclusion in the pre-closure safety analysis for determining event sequences only if they are reasonable; i.e., based on the characteristics of the geologic setting in the human environment and consistent with precedence adopted for nuclear facilities with comparable or higher risk to workers and the public."

Given that provision in the regulation, I see not reason why we can't adopt the same methods we have done, for example, at the MOX facility or at commercial nuclear power plants.

I see DOE being driven to some choices here again that take us in a much more rigorous for a much lower hazard direction.

MEMBER HINZE: Raj, Mahendra, any comments in response to --

DR. SHAH: I think this issue was discussed at length with us, DOE, and I think NEI was involved and OGC. And it was decided that 63.102(f) is not applicable in the way it was applied in the way Rod described it, but it relates to design basis events. Design basis event is 10^{-4} per year, like what they chose to do on MOX facility. It may have been possible, but DOE has used 2,000 in their design basis. And that requires demonstration of performance.

MR. McCUOLLUM: I think the question is performance to do what, to mitigate what hazard? And that is when we need to look at it in a risk-informed perspective.

And I think the Committee is doing an excellent job here is say, "Let's look at this in a broad risk-informed perspective. Let's look at it in comparison to the way we do other things. And does this make sense?"

Simply saying we have this performance objective over here and we're going to assure that it's met without asking the question "Is that the right performance objection?" and I think we were told in two meetings with the NRC that they did not agree with our interpretation of 63.102(f), I look at those words.

And I look at the consistency with higher hazard facilities point that is in those words. And I still ask the question, "Well, why not? Why is it that you can't interpret it that way?"

MEMBER HINZE: If I understand you, Mahendra, this was a call of OGC?

DR. SHAH: Yes.

MR. McCUOLLUM: And they were present at that meeting.

MEMBER HINZE: Comments from Dr. Murphy or Dr. Reiter?

DR. REITER: Well, maybe it is worthwhile just mentioning Bob Kennedy's --

MEMBER HINZE: If you would like to do so --

CHAIRMAN RYAN: Before you do that, if I may?

DR. REITER: Yes?

CHAIRMAN RYAN: I guess I am just trying to summarize in my own mind where we are here. It seems like -- and anybody can correct me if I am wrong -- that the staff's view is that there is a basic criteria. And it sounds like DOE is exceeding that criteria or being more conservative in what they select and design. Now, whether they feel driven to do that or they have decided to that on their own, let's leave that part aside for the moment.

And, Raj, your view is that a design criteria is more consistent with existing fuel-handling facilities or, you know, reactors is not nearly as robust as you said as to what DOE seems to be moving toward.

MR. McCUOLLUM: That is correct. I would say they are being driven to it, but --

MR. NATARAJA: I think we made it clear that there were no design criteria to start with. We don't have any prescriptive design criteria in part-63. We only have a performance requirement to be met.

CHAIRMAN RYAN: Maybe I used the wrong words. Performance criteria. And that performance criteria is leading them to a design that is more conservative than perhaps it needs to be. Is that, my understanding of that, correct?

MR. NATARAJA: It is possible. It is possible one might choose such an approach, which might end up being more conservative than necessary. But that is not being driven by --

CHAIRMAN RYAN: The reason question to ask that would be helpful here is, what is DOE's mind and where they are in all of this.

MR. McCUOLLUM: I have gone as far as I should --

CHAIRMAN RYAN: And we can't go any further than that. So I just want to get that question at least clear that I'm asking a question everybody agrees is a reasonable question.

MR. NATARAJA: I think we have to be careful not to mix up between pre-closure and post-closure. There is one --

CHAIRMAN RYAN: Fair enough. Fair enough.

MR. NATARAJA: Second thing, we should also be making some distinction between the waste package versus surface facilities. There are two different kinds of criteria and requirements.

CHAIRMAN RYAN: Yes.

MR. NATARAJA: And the surface facility design is very similar to PFS or ISFSFI and stuff like that, which are comparable in risk and nothing more robust than that.

CHAIRMAN RYAN: I guess I am coming at this very simply. If we end up with a fuel-handling facility that looks a lot different than the current suite of fuel-handling facilities, something is out of whack. That is just my simple-minded view of it.

DR. SHAH: I was looking at it the same way. I don't expect that it would be much different.

MEMBER HINZE: Could I ask if Kevin as an observer, as a commentator but as an observer, of DOE would care to respond?

MR. COPPERSMITH: Sure. Kevin Coppersmith. I am a senior author of the topical report revision 5 that is DOE's methodology for pre-closure seismic design and performance conformation or evaluation.

The issue here is very simple. There are two parts to the problem. One, what are your design basis ground motions? What are going to be designing to?

And I think that was attempted to put on the left-hand side there for part 50, 52, 72, and part 63. And, in fact, our design basis ground motion, DBGM-2, which would be for the important to safety SSCs that are part of category 2 event sequences, will be designed to the 2,000-year ground motion, the 5 times 10^{-4} ground motion.

Now, that is not specified in part 63. We do have to have design bases. And we need to show how they relate to design criteria. That is only part of the picture.

If we go back to the days of nuclear power plants and regulatory guidance at that time, that was the end. The design basis ground motion, whatever it was, in SSC or even in 1.165, 5 times 10^{-4}, whatever it is, you're done.

What everyone has told us, including OGC from our OGC and your OGC, that, in fact, for part 63, pre-closure performance objectives, particularly 63.111(b), require more. We need to show that we actually perform at a level that allows. And those levels are specified in a peculiar manner, admittedly, by dose criteria and probabilities.

It is unusual-looking. It doesn't look like post-closure. It is not a probability-weighted dose. As I think Brit said very well, it is actually a binned type of approach.

Category 1 has a different set of performance criteria. Category 2 event sequences are different. But we are trying to get into a position where we can demonstrate performance against those performance objectives.

So if you go through the history, as Raj went through it, the topical reports that DOE has put in revisions that are put in front of NRC, always begin with a design basis ground motion. And that is probabilistically based. In other words, where do you enter the seismic hazard curve?

Five times 10^{-4} is correct. It compares well with part 73, more passive types of facilities that have lower risk significance than a nuclear power plant.

Secondly, how will you demonstrate performance? Our rev. 3 showed that we were going to demonstrate performance, referring to 63.102(f) using the same types of approaches that had been done for the IPEEE submittals for nuclear power plants.

We are going to use the seismic margin analysis. We would develop a beyond design basis ground motion and show that, in fact, we had adequate margin against that using all of the approaches that have been used by at least half the submittals for IPEEE.

Twelve months later or 13 months later, word came back from NRC that it, in fact, would not meet 63. Okay? So with a lot of discussion and a lot of look into what had been done for nuclear power plant risk analyses, we have developed a probabilistic approach that will show compliance with those pre-closure performance objectives. And that is in revision 5.

What that does is it uses an approach that does have a pedigree with nuclear power plants. It is basically a convolution of hazard curves, with fragility curves.

The issue, then, is how do you make 63 work when it doesn't look like PRA goals, it doesn't look like post-closure. How do we make it work with this category 2, category 1 event sequence methodology? And that has been the area we have had the most discussion with the NRC and as well as ourselves.

So we have an approach that starts out by first looking at dose and using the consequence analysis to put us in the category 1 or category 2 that helps us identify important safety SSCs.

And then for that subset, which we are finding is relatively small relative to all the SSCs, then we will develop the event sequences with the fragility curves convolving with the hazard curves, and show that, in fact, our probabilities are below the category 2 limit, which in this case is one to two times 10^{-6}.

So there is nothing in this that is 10^{-6} design. If we choose to always comply, we will design everything 10^{-6}. If we choose to save the public money and take a more reasoned approach, we will design to 5 times 10^{-4} and demonstrate compliance with the performance objectives at that level. And that is what our methodology is. That is the way it has been laid out.

DR. SHAH: Well said. Well said.

MEMBER HINZE: Thank you very much, Kevin. That was very illuminating and very well done. Thank you.

Further comments?

DR. SHAH: No. I think he summarized the process very well.

MEMBER HINZE: Let me ask you, Kevin, does this lead to an absurdly robust facility in your -- I realize you're not coming from the design basis, but we are hearing these comments.

MR. COPPERSMITH: The issue that was raised to us -- and we had a technical exchange on this topic with the staff -- was the words -- and we added it to the title -- "performance demonstration methodology." Okay?

I think we have to say -- and I would agree with Rod this is the first time that in design this type of performance demonstration is required. It goes in with our license application. It is part of the PCSA.

This was done post facto for nuclear power plans. It is done, I would say -- for MOX, it was done in a very simplified manner. After all, you are allowed to define highly unlikely yourself.

This is actually a case where the pink boxes are required as a part of submittal, an SAR submittal. So it is unique. And the demonstration has to be in the submittal. It can't be done post facto. It can't be done post-construction.

One of the issues, of course, is how do we develop fragilities for every structure, for all the cranes, for all the systems and components a priori so levels of design detail will be an issue?

The issues of right now doing a fragility analysis drawing on as much as we can from what has been done at other facilities is absolutely essential because we have to be able to take advantage of the fragility work that has already been done at operating facilities. So we have people who are spending all of their time on comparable facilities.

So it is one of a kind in the sense that this is the first time in my knowledge that the actual risk assessment and performance demonstration is part of the design process. That is unusual.

MEMBER HINZE: And the critical part here is trying to get which of those fragility curves should be convolved and making that decision.

MR. COPPERSMITH: Well, that gives you the subset for the evaluation, but then the evaluation itself --

MEMBER HINZE: Sure.

MR. COPPERSMITH: -- of course, there may be unique SSCs to this facility and so on that make it difficult. We do have a number of people involved with industry experience, who both nuclear power plants but also work in terms of fuel-handling facilities, international experience, and so on to help with the fragility work.

MEMBER HINZE: Great. Thank you very much.

Any other comments? The Committee? Staff? Dr. Hamdan?

DR. HAMDAN: One question. On Yucca Mountain, you mentioned the standard defense, five rem. Is this the only 7 and 63-112 or is this a worker standard as well?

MR. NATARAJA: Part 20 covers the worker standards. That's part 20.

DR. HAMDAN: But the seismic --

MR. NATARAJA: It is for the public.

DR. HAMDAN: Right.

MR. NATARAJA: Imaginary individual at the boundary.

DR. HAMDAN: But in the case of a seismic event, isn't the worker impacted more than he would under normal conditions?

DR. SHAH: That comes under part 20.

DR. HAMDAN: I see.

MR. McCUOLLUM: Which I believe is invoked by part 63. So you have to protect your workers to part 20 standards, correct?

MR. NATARAJA: I mentioned in my presentation cross-reference to part 20.

DR. HAMDAN: And Part 20, this is these unusual events, like seismic events, as well?

MR. NATARAJA: No, no. Part 20 is specifically for nominal standard operations. The so-called accident conditions will be analogous to the category 2.

DR. HAMDAN: So the consequences of seismic event is tied to the standard in 63-112, right, which is the five rem defense only?

MR. NATARAJA: Right.

DR. HAMDAN: Thanks.

MEMBER HINZE: Dr. Reiter?

DR. REITER: Yes. Is this our final comment stage?

MEMBER HINZE: No. We will recess for lunch and return at 1:30.

DR. REITER: Okay.

MEMBER HINZE: And at that time, we will call upon you and Dr. Murphy to lead us in some discussion on this. And there will be opportunity to revisit some of these items after some requests.

DR. SHAH: I have to leave at 1:30.

MEMBER HINZE: We will ask Raj to sub us. And at that time, Leon, I would appreciate it if you could say a few comments about Bob Kennedy's remarks.

DR. REITER: Okay.

MEMBER HINZE: Okay? So with that, unless there is someone with an absolutely essential comment, we will pass it back to you, Dr. Ryan.

CHAIRMAN RYAN: Thank you. Thank you, all the presenters and participants. It has been an interesting and productive dialogue so far. I am sure we will continue after lunch.

We will adjourn the meeting and reconvene promptly at 1:30.

(Whereupon, a luncheon recess was taken at 11:57 a.m. until 1:33 p.m.)

CHAIRMAN RYAN: All right, thank you. We'll reconvene our afternoon session. And Professor Hinze, please lead us through our roundtable.

ROUNDTABLE DISCUSSION

MEMBER HINZE: Well, we have scheduled for the next hour a roundtable. And I suspect from this morning's discussion that we may find enough to fill up that and more.

I would - I think we all appreciate the presentations and the comments that were made this morning for Rod and Kevin that weren't part of the presenters.

I'd like to start off if I might this

afternoon with calling upon Leon Reiter to make some comments. And I'll ask - we'll go to Andy, and then we'll open it up to general discussion.

Leon, if you would like to, start us off on your comments on Bob Kennedy's comments if you will, and your reaction to this morning's presentations and discussion.

MR. REITER: The thing that I am thinking about is this issue that Bob dropped the various terms, is whether it's - are these criteria more stringent that for nuclear power plants. And the significance of that, or the lack of significance of that.

And reading through some of the various positions that were taken in some of the documents, the NRC staff in thee letter they wrote to EPRI, and the response they wrote to the - the Federal Register notice - says that these are not more stringent than the criteria for nuclear power plants, and gives some arguments, points out that they are not greatly in design, and what we have to - you can look at the ideas. You have not only single SSCs but you can take the other SSCs, and I'm sure Raj can answer some more of that later on.

There's a comment that BNL reviewed, made.

This is the one where they reviewed the ASCE-CI -

MEMBER HINZE: Brookhaven.

MR. REITER: What?

MEMBER HINZE: Brookhaven.

MR. REITER: Brookhaven, yes, okay. And they were talking about comparisons between existing nuclear power plants and using ASCE-4305. And they said that there is a tremendous amount of difference, lack of consistency, and it would be very difficult to make that comparison. And they said if it does, it would be a major research effort. And one of the reasons is that there are so many - the old nuclear power plants were done really differently, and they were done in different ways in different plants.

I saw some plots here for example, to give you an idea of the lack of consistency, the mean - this is from NUREG-1742, and I got this from Bob Kennedy's overheads, the mean seismic core damage frequency for these old plants when the did the calculations runs from 1.9 times 10^-7 to 2.3 times 10^-4th. So it's like three orders of magnitude. Things like Haddam Neck have had a very high core damage frequency. South Texas Nine Mile Point had a low core damage frequency.

And that is a difficult sort of

comparison. But I think the more relevant comparison is between what we have - between the proposed Yucca Mountain preclosure facility and the new nuclear power plants. There is some commonality - some commonality, it's not clearly the same, but there is some commonality. There is this performance-based approach.

And it seems to me there might be more help, more practical to do those things. And I think that if the commission, and I guess two of the ACNW wants to have some real understanding of the difference in risk, I think the work has yet to be done. And I think that it can be done, and here's an example. Bob Kennedy did some simple calculations, and show the kind of results he got.

Now I'm not going to defend this. Who's that that accused Dan Quayle, he said he's no Jack Kennedy? Well, I'm no Bob Kennedy.

(Laughter)

But what Bob did was that he looked up the Yucca Mountain site - sorry - he looked at the Yucca Mountain site, and he did some very specific calculations based upon the relative - the release frequencies, and for the nuclear power plants he used seismic core damage frequency. And for the repository, he used the - the frequency - not the frequency of reference, but the failure of reference, namely, and I don't know, it's some event that could lead, potentially lead to a release of a large amount of material. And that's where we got that 2 X 10^-6. And when Bob takes into account this required multiplication that you take into account, because you have to multiply the spectrum times 1.67 to make sure you have - make sure that sort of margin exists - then he comes out with the conclusion that the release fractions for what they are - the releases for what they are are about the same for both facilities, both the new nuclear power plants and the old nuclear power plants. And that's about somewhere like 2 X 10^-6, or somewhere between one to three times 10^-6.

And that's where I was sort of - for me I was really kind of startled when I saw that, because I had assumed it would be a lot different.

But of course the big problem here, and the big difference - we talked about as far as risk is, what are we talking about here? On the one hand we're talking about -

MEMBER HINZE: Theron, do we have a pointer?

CHAIRMAN RYAN: It's helpful to then if you describe what you're point at for the record.

MR. REITER: Maybe I can just do this -

CHAIRMAN RYAN: I don't think you want to point that at peop0le.

MR. REITER: What I'm saying, we're looking at two -

CHAIRMAN RYAN: Wait, you need a microphone.

MR. REITER: We are talking about two sort of damage states. For a new nuclear power plant, it's seismic core damage, and for the repository, it's that something that has the potential to cause release. I don't know what the exact words.

MR. NATARAJA: You have to set the boundary for Category 2.

MR. REITER: But the event, the event we're looking at -

MR. COPPERSMITH: It's beyond Category 2.

MR. REITER: So the question is, in terms of risk considerations, this could be a lot different than that. So to me what's needed here is to fold in, given these core damage, or given you have this release what are the consequences of that. That would give you an idea of what your risk is. And if you could somehow attach a probability to it.

So if you go to the next slide. As Bob has concluded, he said the seismic requirements for a repository preclosure facility achieve about the same release frequency as that achieved for seismic core damage frequencies for new nuclear power plants.

That's a pretty strong statement. But to me it still is missing the other part: so what? So what are the core damage, what's different?

I think this is the kind of thing if somebody wants a serious answer to the question that was posed to the ACNW, I think we have to have this kind of a study to do it. You have some inklings of this. But I think something like this would add greatly to help somebody make a decision if they want to make a decision.

Now I don't know what they're going to do with it once they have it. Are they going to change the regulations or not change the regulations? I don't think that's the issue.

But there is - and I think Rob raised this - there is the issue still in the back of my mind a little bit that, what's that section in the -

MR. COPPERSMITH: 102(f).

MR. REITER: 102(f) which says that you don't want - what's the exact wording?

MR. McCUOLLUM: It basically defines reasonable as consistent with established precedent at equal - hazard facilities.

MR. REITER: So I don't know to what extent, and maybe Roger can answer this, is that still being considered, or is that being just completely supplanted by the just looking at the 10^-6 -

MR. NATARAJA: Well, that was more of an issue in Part 60 than in Part 63.

MR. REITER: It doesn't appear in Part 63?

MR. NATARAJA: It appears, but it's not reflecting what you are doing here. Our OGC has told us that's not an issue that --

MR. REITER: Okay. As a lay person, it sort of sticks in my mind that we're telling you one thing, and trying to do something else is somehow they should - they should somehow resolve that somehow.

It doesn't seem to me, at least the stuff that I have seen - I haven't seen a lot - it hasn't been adequately resolved.

I can understand some of your concerns about that. It's not to say that this is the wrong way to go. The idea of you know of risk informed performance based seems to be really - it's a good thing. It's time has come. And we have to use it carefully.

MEMBER HINZE: How can we dismiss something that's in 63? I don't understand it.

MR. REITER: I don't understand.

MR. McCARTIN: Tim McCartin, NRC staff. Part of 102(f) that people are referring to, it's talking about initiating events. And the intent behind that is, when you're doing this analysis you're looking at initiating events that are considered at other facilities. And you would consider the same kinds of - same kinds of initiating events in the context of the preclosure safety analysis that you do for other facilities with comparable risk.

MR. McCUOLLUM: But nobody considers a 3 g earthquake, and that's the initiating event of interest here is a 3 g earthquake.

MR. McCARTIN: Well, there is nothing in the regulation that requires consideration of a 3 g earthquake.

MR. NATARAJA: Where is this 3 g earthquake that we have been talking about?

MS. KELTON: Well, it's in DOE's analysis. It's certainly been a factor in the TAD performance specification. It was described at the end of your TRB meeting as being the designing earthquake for the surface facilities. So it's out in the public domain.

And I believe, and again this is where I'm getting beyond my area of expertise; I'm not the seismologist here, but I believe DOE has - and maybe DOE - maybe DOE should - I'm not going to say what I believe. I'm going to let DOE answer that.

MR. REITER: I thought that 3 g has to do with tipping over the aging cask.

MR. McCUOLLUM: Well, it does.

MR. REITER: But it's not an overall design for the whole -

MR. McCUOLLUM: But why do the casks have to not tip over in a 3 g earthquake?

MR. REITER: It's the scope. It's not a design with preclosure scope. That's one thing. It's a specific design. What DOE - you've got to ask DOE why in this particular case they chose that way. Maybe Kevin has the answer, I don't know.

MR. COPPERSMITH: I can only talk to the methodology, not the particular application at some SSC. But the design basis ground motion for DBGM-2, for Category 2, to mitigate Category 2 event sequences is 5 X 10^-4. It's a 2,000-year ground motion. So you enter the hazard curve at 2,000 years.

Now that is not enough for performance

demonstrations. It's not enough to show compliance with 63.111. You need to do something else. You need to carry it to the next step.

So given the ground motion, what are the effects? What are the consequences?

So that 63.111(b) goes through the process of what you need to consider. Now we have to - we have to go beyond Category 2. In other words we want to show that we can screen out Category 2 event sequences, either by showing they're less than five REM which by definition moves them out of Category 2, or show they're less likely than 1 in 10,000 during the preclosure period, let's say 10^6 for containments.

So de facto, the 10^-6 probability becomes our goal. And how can you achieve something being less than 10^-6? Well, you can design it for 10^-6. Now you need - as it reaches and exceeds that 10^-6th ground motion it can completely fail but you've achieved the probability.

I don't think there is much plan to do that with very many SSCs at Yucca Mountain. There'll be design a couple of orders of magnitude back, five times 10^-4, and then the capacity-fragility analysis will show that in fact we achieved the additional capacity needed to meet the 10^-6.

That's the way 99.9 percent of them -

MR. REITER: I know, but I'm talking about the other .1 percent. In this case if it's correct that a point 3 g design value was picked, not something that was shown that there is margin to absorb that, but a design value. And that sticks in some people's craw as to why was that being done. Was that being done due to the cost-benefit analysis?

MR. COPPERSMITH: I can't speak to it. I don't know.

MR. McCUOLLUM: It is, when you go to the 10^-6 ground motion is that what gets you to the 3 g?

MR. COPPERSMITH: Yes.

MR. McCUOLLUM: Then that's exactly the point I was making earlier.

Let me make one other point, because this comes up again, and we've never, nothing else has ever been - 3 gs has never been looked at before. We never had to deal with this before. For anyone who has studied seismic PRAs for nuclear power plants, numbers that large and larger are used all the time. Seismic hazard curves are by definition extended out to very low probabilities of exceedance, 10^-6th, 10^-7th is common. And at sites like Diablo Canyon 10^-6th, 10^-

7 are very high ground motions, and they are convolved appropriately with the fragility curve.

And the fragility curve shows the probability of behavior, nonacceptable performance as a function of ground motion. And it's the convolution of the two. You get very high ground motions. You have a very high probability of failure. But the risk contribution goes down because the probability of them occurring is going down too.

So typically the contribution to risk is a balance between that high level of ground motion and high probability of failure, and their probability of occurrence by definition.

So the risk contribution, usually out in the tails, is very low, because the probability of that happening is so low. And it's done all the time, this type of - I'm not going to say that we don't have high ground motions at the tails of the hazard curve; we do. But other sites do as well.

MR. McCUOLLUM: But if you want to make the case that it can't happen and not convolve all those curves, then you do have to deal with the tails of the distribution.

MR. COPPERSMITH: If you back to Tim, what he said is, 102(f) has been interpreted or better or for worse by the lawyers on both sides of the aisle as just limiting initiating events. Just that input ground motion. And if it just says, you have to consider earthquakes because other comparable facilities consider earthquakes, facilities with comparable risk significance or higher, then we're doing - we're including only those things that other power plants and others --

If it is some level of ground motion, or some level with its probability, that's a much more specific case. We try to find - we, DOE - try to apply 102(f) to mean that a methodology, a seismic margin analysis methodology, could be used for performance demonstration per 63.111, and it was found to not be acceptable.

So right now our interpretation of 102(f) is very narrow, that it just simply says you got to consider things like earthquakes, because other facilities do, and wind and flooding, and not much more than that.

MEMBER HINZE: Leon, I interpret what I've concluded from your comments that this kind of statement is not really valuable, because you aren't comparing the same things.

MR. REITER: No, I think it is - Im' sorry.

MEMBER HINZE: Ad that what you are suggesting is that in order to have comparable comparisons, that what would have to be done is to do some analytical study.

And what I've said is what you're driving at, what kind of analytical studies do you envision?

MR. REITER: Well, first of all, I think this contributes an awful lot. We haven't seen anything like this before. I think it's really - the only thing is that it raised some questions about should we go further than that, and Bob is not going to extend that. And I think it's worthwhile going further than that.

And an attempt to - with experienced analysts trying to work out what the consequences were, what the probability was, and try to see if you can draw some conclusions about, if one is more concerned than the other, and to what extent.

I don't have any specific analytical studies to try and extend this into risk space, into real risk space.

MR. COPPERSMITH: Can I make one comment on this, Leon? Maybe go back one slide. Is that where he actually compares the 2 X 10^-6th with the 1 to 3 X 10^-6th? And Bob worked with us on the topical report. He's very aware obviously what's going on with the new plants, the old plants, the risk basis, the results of IPEEE and so on.

Yes, let's stay to the core damage frequency of 1 to 3 X 10^-6th comes out of a selected subset or the implications of the application of 43-05 or some other new standard.

It's not very different when you look at his range or the old PowerPoints too, it's sort of the central part of the range of core damage frequency.

The bottom one, though, the release frequency for the Yucca Mountain repository preclosure, the 2 X 10^-6th was 1 in 10,000 during a 50-year performance life let's say. There is per event sequence.

So let's say the top one is an aggregate integrated PRA model, with the full system logic, all the different things going on with their relative frequencies and so on. You put them altogether, you get an integrated core damage frequency.

The 2 X 10^-6 for Yucca Mountain is per event sequence. So there are more than one event sequence, seismically related event sequence, which I would think there probably would be, you can imagine building collapse being one, or a crane failure being another, and work your way through, they in sum would be in proper logic would represent the core damage frequency sort of comparison. Seismic. So if you were going to make a comparison, it should be done either on an aggregate risk model, which I don't think Yucca Mountain has any intention of developing, because they don't have to. Or take individual event sequences from the existing PRAs at PowerPoints and compare those. That would be a more reasonable type of comparison, because the 2 X 10^-6th is for individual event sequences. There is no, for Category 2, event sequence. There is no requirement to aggregate a full system model to get aggregate risk.

MR. REITER: I'm not arguing about - I said that Bob Kennedy put this together. I have great respect for Bob Kennedy. But this thing, you have to look at the various aspects. If it demands not only going back and looking to this, to try and as much as you can make a quote apple-to-apple comparison. That's what the thrust is.

MR. COPPERSMITH: So I would conclude, if Bob was here, he would - I'm no Bob Kennedy either, but having thought about this for a little while I would conclude that the Yucca Mountain criteria, as onerous as they are for performance demonstration, I'm not going to argue that in fact as an applicant DOE has to do more than any other applicant has had to do for preclosure seismic. But when it comes to the actual criteria they may not be, they may actually be that the PowerPoints are a little more conservation in aggregate risk than an aggregate goal would be for Yucca Mountain

MR. McCUOLLUM: Well, isn't that an academic distinction though? I mean what you're comparing is a criteria versus what you really have to do? The only thing that matters is what you have to do to get licensed.

MR. COPPERSMITH: It's what you'll have to do to demonstrate compliance with 63.111.

MR. McCUOLLUM: Right, that's what really matters.

MR. COPPERSMITH: That's what matters.

MR. McCUOLLUM: The fact that the criteria may be comparable, if you have to go beyond the criteria to meet ISG-1 and the Part 63, then the comparisons between the criteria is simply an academic comparison.

MR. NATARAJA: What you're saying basically is that the PCSA requirement is an additional requirement for Part 63 and it is.

MR. McCUOLLUM: It is, I agree.

MR. NATARAJA: Other parts of the agency do not require, once you show them the design side equation, you're done. But you have to do this here for Part 63.

MR. McCUOLLUM: I agree, and I would ask getting back to risk informed space, is that extra stuff warranted by the risk? The burning question that I have, and I'll ask you, Leon, when they say release frequency, what magnitude of release are they talking about?

MR. REITER: Well, I don't know. That's what we have to - I mean I can't provide the answer to that.

MR. COPPERSMITH: This is Category 2 event sequences that would exceed 5 REM at the boundary with the public.

CHAIRMAN RYAN: By how much?

MR. COPPERSMITH: Any amount.

CHAIRMAN RYAN: In reality, what do you think they might calculate out to be?

MR. COPPERSMITH: You just used 5 REM, whatever it is.

CHAIRMAN RYAN: That's not my question. If you did calculate the event sequence and it was over

5 REM would it be 5,000 REM or 6 REM?

MR. COPPERSMITH: I haven't seen the results. Those analyses are going on right now.

CHAIRMAN RYAN: You made an important point. It's an additional requirement. There are several facilities that have different requirements.

MR. COPPERSMITH: That is the crux of our --

CHAIRMAN RYAN: Are we accepting that as okay?

MR. NATARAJA: I'm not in a position to answer the question.

MR. STAMATAKOS: The - it's a different requirement. The point of the requirement is that we are - with the performance based try to achieve flexibility. We're trying to take away specific design requirements that they would have to meet. And the substitute for that is a lot more freedom to demonstrate simply how things perform.

CHAIRMAN RYAN: I'm not an expert on this topic technically, nor did I stay at a Holiday Inn Express last night, but it seems to me there are some disconnects here.

MR. McCUOLLUM: I mean the fact of the matter is, you do start out, and I apologize for jumping the gun when I was showing Mahendra's graphic. You do start out with a 10^{-4th} earthquake, but that's not enough to meet this additional requirement. You have to -

MR. STAMATAKOS: We don't evaluate the design on that. We're not - there aren't 0800 criteria that we're requiring that design to meet. We're not - we're not doing a full analysis of that design. What 63 asks for is the PCSA.

So how we - DOE has complete freedom in how it wants to achieve those performance objectives.

MR. McCUOLLUM: It can do any design it wants.

MR. STAMATAKOS: But those casks sitting out on that aging pad didn't get to that design on the 10^4th, the 10^4th earthquake. They got there on the 3 g earthquake.

MR. NATARAJA: Of course if you could make a distinction between surface facilities and the waste package. There are different for waste package than for -

MR. McCUOLLUM: Aren't they going to get driven in the same place on the surface facilities, because the same requirement is in effect? Same -

MR. STAMATAKOS: How they choose to get

there is - those assurances you'll take up with them, as I would say a 3 g earthquake. We've looked at the hazard, and if 3 g is unrealistic then why is that there? I mean that is another question you should ask DOE.

MR. McCUOLLUM: I understand how - now please, I'm not the seismologist again. It's been awhile since I stayed in a Holiday Inn Express. But my understanding is that at 1 X 10^-6th when you go on the curve that's what gets you to 3 g.

MR. McCUOLLUM: That's - they also have derived that information.

MR. STAMATAKOS: If that is truly the case it's unavoidable whether you're talking about a surface facility or an aging pad.

MR. NATARAJA: They may have confidence that they can meet that without really being too conservative. Because they may have other requirements that will give them that kind of strength and robustness, it will withstand the 3 g. That may be the reason it's there because somebody is insisting they should design it against 3 g.

MR. McCUOLLUM: Well, yes, they go to things like 2-inch thick pad specs and 4-foot thick walls because it becomes a better choice to them to design to the tails of the distribution on the 3 g earthquake than to convolve all the fragilities in the hazard curves for all those components all the way through the facility and get into an intricate design process that could become -

MR. NATARAJA: Well, I think the thicknesses and other things because of the postclosure requirements.

MR. McCUOLLUM: No, there's no postclosure requirements on the surface facilities.

MR. NATARAJA: No, I'm saying the waste packages.

MR. McCUOLLUM: I want to be perfectly clear on this. I have no problem with the thickness of the TAD waste package. The industry is very happy with that. Our problem is that the aging overpacks and the surface facilities at Yucca Mountain.

MR. NATARAJA: The surface facilities as you saw will be designed to 5 X 10^-4. And everybody is saying that is comparable -

MR. McCUOLLUM: Well, that's where they start out. But when you go down this - and I think DOE is telling you they don't know yet, when you go down this additional road you start out with that 5X10^4th, but then to meet this performance analysis, you have to go to the 10^-6th.

MR. NATARAJA: You saw Mr. Kennedy's conclusion, that it gets what you need, 2 X 10^-6th for 50 years is exactly what the requirements is. Starting with 5 X 10^-4 design to achieve that one. That's stated in his conclusions.

MR. McCUOLLUM: But can you stop there?

MR. COPPERSMITH: Let me, just to step back, and we tried to develop this a little bit in the topical report, rev. 5 if anybody wants a copy of it, we an sure make it available.

There are two parts to the problem of seismic safety, regardless of whether it's preclosure for Yucca Mountain or it's seismic safety for any other facility. The first is the design basis. This is the level you're going to design to, and keep the response essentially elastic.

The second part of the design criteria you're going to impose, acceptance criteria and the like, that you will design that will add capacity, will add margin to your facility beyond the design.

And we are committing to NUREG 0800, in the design criteria. It's been shown by studies that the amount of margin that's added by going to 0800 is significant, a big part of AWE 4305 was a demonstration of that margin. And of course this was some of the discussion that Bob Kennedy has had, is how much margin. It could be as high as factors of 50 to 100 beyond the design basis. So if you're designing to 5X10^-4, or 5X10^-6 may be given just due to the additional capacity that you've added, the margin that you've added. So we are committing to a design basis of 5X10^-4. NUREG-0800 design criteria, and acceptance criteria, and we will demonstrate, given those two, that we meet these performance objectives.

Now that's the way it's done. You can move the design basis up if you do the analysis and find that in fact the event sequence doesn't meet the 10^-6th you can add to the design. You can go from 5X10^-4 to 10^-4, or go to 2X10^-4. Yu basically work your way on the hazard curve, add more to the design side.

More likely, rather than change the design basis, you would add additional margin. And this is the issue of the thickness of the walls, the 4-feet thick walls we always hear about.

Number one, those are primarily - their thickness is primarily for radiation shielding. But we analyze them given their thickness and the rebar and everything else as they are. If we comply we o through the process of convolving the hazard curve, with the fragility curve. If we're beyond 10^-6th we're done. We've demonstrated compliance.

If we don't, we have the option of going back and adding additional margin. And the topical report discusses that, that potential. This is what was called an interactive. That has to all be done before we get the application in.

But the issue of, it's two separate part. So we shouldn't be talking about being forced to design to something. We're in fact committing to a design basis of 5X10^-4 and the use of NUREG-0800 to ave sufficient margin to demonstrate compliance. The compliance demonstrate is additional work, and it's what's happened in the nuclear power plant area is, they did it post facto, IEEE and so on, was done post facto.

In Part 70 world they're requiring much of that to be done as part of the application, the CA and probably the receive and possess would be more.

In our case it's been interpreted by OGC and others that Part 63 requires that compliance demonstration to be in the application.

MR. HILL: Britt Hill, NRC staff.

There is a third part of the performance or compliance demonstration that also needs to be mentioned here, and that is, the consequence analysis is also an intrinsic part of the performance analysis in preclosure. If you show that the design is not - does not have the capacity to withstand one of these events with a frequency of less than 2X10^-6th per year, another option is to demonstrate that the radiological dose consequences of that event sequence would be less than 5 REMs per year to any real member of the public.

So it's not like there is a zero release criteria on here. Releases are still allowed under some of these conditions. You just have to meet the performance based risk informed consequence standard as well.

So there is a third part of the compliance demonstration that is a variable to the applicant if they chose to use it.

DR. HIRSHFELD: Building upon that, let me ask a question. Are we comparing the right thing, or is Bob comparing the right thing when he compared seismic core damage with release frequency? Because in one case you're dealing with, as Britt says, with something less than 5 REMs, and the seismic core damage, I don't know what, but it must be much more -

MR. REITER: I think this was easy to calculate for him, in his first attempt to do that. I think that's what he was doing.

MEMBER HINZE: It's just that it's easy to compare.

MR. REITER: At this point, yes. Just to - it takes you up to this consequence space, and it doesn't go into it. Doesn't go beyond that.

MEMBER HINZE: Well, what would be the appropriate - they're different, so maybe you can't compare them.

MR. REITER: Well, I think that the much better chance of comparing them here than with the wide range between old and new nuclear power plants. Because there is some commonality here.

MR. McCUOLLUM: Well, in the fuel handling facilities, a lot has to go wrong for a core damage accident. So me, I don't see that as apples to apples. Fuel handling facilities are much simpler facilities.

There was a way to do an analysis comparing the fuel handling facilities at a new and an old nuclear - and we haven't done this either -

MR. REITER: You can compare health

effects. You could reduce it to a common denominator, health effects.

CHAIRMAN RYAN: That's a terrible metric?

MR. REITER: Terrible metric?

CHAIRMAN RYAN: Terrible metric. There are no health effects at these dose levels that you can really measure and distinguish from similar - I know it's done, but it's just wrong.

MR. REITER: Is there some other dose? Stick with dose.

CHAIRMAN RYAN: That's at least a fair mead, when you multiply by something where you have a very wide uncertainty band that adds no value to the relative comparison, it's a waste of time.

Can I ask a dumb question? How much fuel is going to be in this building versus what's in the power plant?

MR. McCUOLLUM: My understanding is, in most of the buildings, less, because right now the power plants are storing all their fuel for the life of the plant. And in these Yucca Mountain surface facilities it's going to be a fairly transient thing. It's going to go a few -

CHAIRMAN RYAN: All that being said, give me a number. Is it ten times more to fuel in one reactor's fuel pool, or one tenth? Anybody got a clue?

Andy.

MR. KADAK: In the building it's supposed to be a processing plant where you really don't store very much unless the DOE decides to open up every darn can that they get that is already prepackaged as a disposable waste container.

CHAIRMAN RYAN: That's kind of my point. The idea that you'd have more fuel than exceeds the fuel pool has gotta to be pretty slow.

MR. McCUOLLUM: I would say it's impossible. I don't think the facilities are designed with the sizes of pools we have in our reactor.

CHAIRMAN RYAN: Or the special racking and all that, the high density packing and all that stuff. So I'm struggling, what's the source here? That's got to come into this risk assessment. And I'm thinking about 5 REM. How do we get 5 REM at the nearest member of the public. That's a big accident, and not so much fuel when you come right down to it.

MR. COPPERSMITH: Those calculations are being done, different source terms.

CHAIRMAN RYAN: That's where the light is going to be shed on this darkness here, what is the first pass at what this looks like.

MR. NATARAJA: It looks like - I mean I am not an expert in this field, but they tell me there is a lot of uncertainty in the calculation of the source term. That's one of they reasons why they're trying to avoid going into -

CHAIRMAN RYAN: Fill up. But the inventory to start with is a small fraction of the inventory that's already to be assessed in the fuel pools. It's just as difficult in the fuel pool to derive the source term as it is in Yucca Mountain's fuel pool. Same set.

MR. McCARTIN: Tim McCartin. And that's exactly the point of the regulation, and why we did it the way we did. Where possible people would do a probability and consequence calculation, and get a sense of what kind of consequences you have and what kind of probabilities. And that is what risk informs about.

CHAIRMAN RYAN: Somehow it gets twisted back to a deterministic bidding. And that's where -

(Simultaneous voices)

MR. McCUOLLUM: That's where - and I would maintain that you weaken the value of a risk-informed approach if you are only going to look at the probability. You have eliminated half of the information.

CHAIRMAN RYAN: Absolutely.

MR. McCARTIN: And that makes it a harder problem to deal with. But that was not the intent.

CHAIRMAN RYAN: It's actually a third of the risk informed.

MEMBER HINZE: What I hear from Kevin though is that DOE is performing these calculations, which means one year from today we will know the answer to this question.

MR. NATARAJA: The license application should have an answer to this question.

MR. COPPERSMITH: I didn't explicitly mention consequence. The consequence analysis is done first, because that's how you decide if you're Category 1, Category 2. And I apologize, that's what's done in the first place.

And then only those Category 2 event sequences that show they have the potential to exceed 5 REM will proceed with the rest of the analysis.

So that initial screen is very - very valuable.

CHAIRMAN RYAN: We had a question back there.

MR. KADAK: This is Andy Kadak again from the waste board again.

I'd like to ask Kevin, how are you going to deal with the transport cranes, and you know, if you figure those numbers, you're probably in the space that says, I will drop a cannister on the spent fuel in the pool, and that will cause some kind of a release.

In today's world, you know, in the reactors, we design single failure proof cranes, which are essentially eliminating that from a probabilistic failure.

And from my past interactions with NRC, humans will fail 1 in 100 to 1 in 1,000 times. Okay, that's their probability of failure per event. You multiply that by some mechanical failure, electric motor failure, you can conjure up a fairly high likelihood relative to what you need to meet as a standard, a performance standard, to this, to 10 CFR Part 63.112.

So I'm wondering, how do you deal with that in your assessment? And is that going to be able to show that you won't get the 5 REM? Because somewhere you must have already done the analysis that says you have Category 2 events in fuel facilities.

MR. COPPERSMITH: Yes, the first analysis, the consequence analysis, would show that you have the potential to exceed 5 REM, or you wouldn't consider it to be in a Category 2 event sequence.

The second part of the analysis is dealing with the actual probabilities of those things happening, let's say the probability of the crane failure, and the probability of the effects, the damage that might occur. And then the probability of the release given that it does occur.

That logic, and those probabilities, are all fragility analyses. And they're done in the same type, the same way that a nuclear power plant would do its - in fact all of the same people involved in PRAs for nuclear power plants - or not all of them, but quite a few are involved in our project. That is the - that is the nature of the business.

I won't say that the design criteria won't be imposed that are comparable to the single C, you know, fail-safe type approach. It may be that there are some SSCs that are so vital that they lead to event sequences that have high probabilities of exceeding the 5 REM, and design criteria may be imposed that are severe that preclude that from occurring.

So we're trying to basically do an analysis of those that's realistic. And we have members from industry with experience of doing these exact type of calculations for PRAs involved in this study.

MR. KADAK: I was just trying to respond a little bit to Tim's comment about this should be better. It's not always the case.

MR. COPPERSMITH: One of the issues, and this does come up on Yucca Mountain, is that we have to draw on - because this isn't - even though this is a first-of-a-kind facility in some ways, in other ways it's not. And many - Bob was here. He said hey, we can use the crane information. We can use this equipment information. He can go through the information that exists that has been developed for PRAs and fragility analyses as part of IPEEE for example. And we can use that, or modify it appropriately, for our submittals.

We're trying to draw on as much industry experience as we can. And of course NRC itself has done a lot of work in this area.

MR. McCARTIN: Could I ask a question, though? The way you posed your answer, and you drop a container inside a building, and you're getting a 5

REM dose, 18 kilometers away?

MR. COPPERSMITH: Number one, it's not 18. I think the closest member of the public -

MR. NATARAJA: Eleven kilometers.

MR. McCARTIN: Is that what it is?

MR. COPPERSMITH: Right now, the consequence analyses would tell us whether or not. I'm just setting up a hypothetical in the same way that the appendix in ISG-1 sets up a hypothetical. It's very comparable.

MR. NATARAJA: And I also thought that these were not based on accurate calculations, but some simplifying assumptions. There is a potential -

MR. McCUOLLUM: That was a bounding case. Risk, we want risk informed.

MR. COPPERSMITH: But it's not bounding. Right now the first step is to screen out those event sequences that would not lead to an exceedance of 5 REM. Right now the number of SSCs is thousands. We want to screen that down to those that are involved in event sequences that could lead to an exceedance of 5 REM.

MR. HAMDAN: How does the 5 REM compare with the standard at nuclear power plants?

MR. COPPERSMITH: I would ask those that

frame the standard to compare. Tim could probably do tat.

MR. HAMDAN: How does the 5 REM compare with the standard at a power plant?

MR. McCARTIN: I do not know the nuclear reactor regulations. So I'm not going to try that one. I don't know if there are any people that from NRR that know that better.

MR. HAMDAN: I mean could it be that the standard is too stringent maybe compared to other facilities that we know about?

MR. COPPERSMITH: It would be appropriate for someone to speak to Part 70, or MOX, Part 72 for ISFSFIs to see what these -

MR. NATARAJA: It is the same for 72. 72 requirements are exactly the same, 5 REMs.

CHAIRMAN RYAN: Reactors are completely different, because they have to do that goofy cancer estimate calculation.

MEMBER HINZE: Do all of your discussions continue on for this long, Leon? This lengthy discussion. I'm wondering if you had further comments.

MR. REITER: Just the basic idea that I think there is something to be gained from studying this more. If the commissioners really want to answer that question.

MEMBER HINZE: But you agree that we will know the answer in a year?

MR. REITER: I think you'll be closer to it.

CHAIRMAN RYAN: Dr. Murphy.

MR. MURPHY: Yes, I had three points I wanted to make. I'll say starting with building on Leon's comment about the appropriateness of trying to do - if the commission wants it, to understand what this term, less stringent requirements than associated with a nuclear power plant, is all about, looking at the consequences there. I think that would be an appropriate thing to do.

But there is also a flip side to that that goes back to Roger's comment that you've got the other side of the boundary. And that s that they need to be, or are about as equivalent to the consequences associated with a fuel handling facility.

I think that represents as open-sided a boundary as the other. And I think very definitely if you look at these sorts of things, it's not going to be a linear phenomena. I don't think you're talking about three points on a - call it a risk or a consequence plane, that's defined by the three kinds of facilities, whether it's a nuclear power plant at one end, and then the fuel handling facilities at another end, and Yucca Mountain over there some place else.

And if we are really interested, if the commission is really interested, in pinning this down, that that part of the process is also going to have to be looked at.

The other two points I guess were that I think Mahendra's slide #5 in my mind put this into a very definite perspective in that it showed how in some sense Part 63 is quote unquote an outlier with reference to the other pieces of seismic regulation or seismic guidance within Part 100.

Yes, Part 63 is different. It does definitely have a performance objective that the others don't have. But I don't see that as a particular impediment or an issue associated with the regulation.

It makes it a little bit more difficult to I'll say a little bit more difficult to implement, because I don't have to implement it at this stage. I'll say DOE and Mahendra, NRC folks here, have got to implement it.

But I think it's an acceptable difference. And I think it is in an engineering sense a workable difference. I think we've seen a fairly good indications of that in that DOE is, as I understand the words now, is willing to accept and make use of the interim staff guidance one, and had not - may have problems with it, but have not been really vocal or objecting to it, so I think the staff is in a good position there.

The other point is that ASCE 43-05 has indeed been accepted by the commission in Reg Guide 1.208, the performance based safe shutdown earthquake determination to put it in quick terms.

We definitely accepted portions of ASCE 43-05. I think it was basically the first two sections or the first two chapters, depending on how you want to call them, that as Goutam indicated this morning got to the specification of the hazard load that was associated with nuclear power plants.

It does nothing to look at the capacity, which are in the last three, I think three or four chapters, of ASCE 43-05, not that the commissioner or the members had particular problems with them, other than they had things in them that we would want to study and consider exemptions from - exceptions to. So

I think it's a worthwhile document. And I'll say, yes, we've also made use of a lot of the thoughts and comments that Bob Kennedy has put into I'll say this presentation that we've gotten as written material. He has made that presentation to the commission staff on a number of occasions for the benefit of power plants.

He has also made that presentation I'll say to a SMiRT conference and was very well accepted, received, and I think we will probably go ahead and in the long term, which may be more than five years, begin to pull the rest of that into the package of guidance and regulation for the NRC.

But again it also may be a possibility that ASCE 43-05 will be replaced by ASCE 43-10 by then. But that's another issue.

Those were the three points that I wanted to make out of today's presentation, discussions.

MEMBER HINZE: May I ask you, going back to this last point, is 43-05 under revision of any sort?

MR. MURPHY: No, 43-05 is out in final form, and I don't know that anybody within he ASCE community, including Goutam who was a member of the writing group, has been so audacious as to suggest that it's time for 43-05-B or 43-10 as I alluded to.

I think it's at the stage sold for the time being.

CHAIRMAN RYAN: Is there anything more, Andy?

MR. MURPHY: I think that's all I had to bring up at this moment.

CHAIRMAN RYAN: Well, those are very insightful comments. We appreciate them.

MR. HAMDAN: Yes, I have a question for Kevin. Could it be that we are worrying about something that we will never realize, meaning, that yes there may have been a preliminary calculation of 3 g but that was just a first cut back of the envelope, too conservative. And when DOE looks at the inventory and does all the work that needs to be done, and the source TMO, to have certification when the license application comes the design will never, will not be anywhere near 3 g?

MR. COPPERSMITH: I can only speak generically. The design basis ground motion for Category 2 event sequences is 5X10^-4, which at the present time is somewhere between .5 and .6 g at Yucca Mountain. I don't expect it go down much or up much. That's what nominally being used for all SSCs. Then an analysis needs to be done of the capacity, the margin beyond that number to achieve 10^-6. And if that margin analysis is very easily done, it's highly robust, perhaps the design basis would be changed to a higher number like 3 g or something such that it's easy to demonstrate compliance.

But otherwise the plan and the analyses that are being done are on the basis of that design. As curves are being convolved with fragility curves, and we're going forward the way a typical risk analysis would be done.

MR. HAMDAN: But do you see going to 3 g where they do the -

MR. COPPERSMITH: The hazard curves go beyond 3 g.

MR. HAMDAN: Based on real data?

MR. COPPERSMITH: Based on the best data that we have available. There are attempts, as people know, in the postclosure world, to limit the maximum size of ground motions. This is a research area in the seismology field. We'll take advantage of any of that information that either we develop or the community develops.

But if you look at the convolution or hazard curves for any site worldwide you'll see that they extend to very large ground motions at low probability. So do we.

I had one question, Bill, that I wanted to ask to Leon and probably to Andy. If we did this study to compare and make it sort of apples to apples comparison between these design - actually seismic performance objectives, really not design criteria but performance objectives, as stated in 63.111, and compare them to nuclear power plants, since we were making a light comparison. And we find that we in fact, who knows, say we're more conservative than power plants, or less conservative, how does that feed into decision making? It seems to me they would be valuable analyses to have prior to the rulemaking, Part 63, but how could we possibly use them as applicants. I'm trying to see how they possibly could provide any use to us at this stage.

MR. HAMDAN: Too late.

MR. REITER: I think the issue was raised because the ACNW got the question. The commission, they're the ones who are asking it. That's my assumption. I don't know if that's true or not. So how the commission would use it, I don't know.

MEMBER HINZE: I don't think anyone wants to second guess. But it's too late in the game.

MR. MURPHY: I think Leon's comments and mine both were premised on the fact that five great

Americans, as they're referred to, asked for, demanded it, and wanted that information to go ahead and make some decisions.

Now, I don't think at this stage it's something that I would recommend we pursue at all. It might give us an answer. But the bottomline is, we don't know what to do with it.

MR. KADAK: This is Andy Kadak again. I think the reason the commission asked the question, not having spoken to them, is, are we going - is the regulation as it's implemented, is that making any sense technically.

And I think this is a technical body, as is the waste board a technical body. And we're trying to make sense of, is this the appropriate thing to do technically. If as you say the reason that we're making the surface facilities more robust is for wind and tornado loading or airplane crashes. Let's do it for that reason. Let's not fudge it because we can kind of cover it with a much higher seismic designs.

So I think we're all trying to get to the bottom of the technical question. I think if the commissioners were told that this criteria isn't really appropriate for surface facilities at Yucca Mountain, because it's way out of line relative to what we're now doing for equal facilities all around the world that handle fuel, they might decide - whether they will or not - maybe we ought to fix the regulation and make it appropriate. I mean why else ask the question?

MR. McCUOLLUM: If I could I think the question is still relevant, because we are about to begin something known as a licensing process. And in the licensing process the safety case for Yucca Mountain will be tested.

I think of all the things that have been said here, there are two things that are not in dispute. Number one is that what's being asked for here by ISG and the interpretation we have of Part 63 is without precedence. We are trying to do something that hasn't been done before.

The second truth is that we really don't know what the ramifications of that precedent are. And I think as we're going to try to look at this thing under the scrutiny and the bright lights of the licensing process, we should know that.

And when we have about 100 of these, depending on how you look at the two-unit plants, we've handled 56,000 metric tons of used fuel. We've got 30 aging pads out there where the fuel has been taken out and parked in things that don't have this 3 g tipover requirement.

It's very much still a relevant question as to why do we have to do this way.

MR. NATARAJA: Just a small correction. There is no 3 g tipover requirement.

MR. McCUOLLUM: Well, the 3 g - no, I know there's no requirement, but somehow we got there.

MR. NATARAJA: Somebody made an interpretation that they had to do it.

MR. McCUOLLUM: That's part of that second point which is, we really don't know the ramifications of it.

CHAIRMAN RYAN: Somebody made an interpretation that they'd have to do it. It's a requirement.

(Simultaneous voices)

MR. McCUOLLUM: He's saying it wasn't NRC that made that interpretation.

mR. NATARAJA: They didn't require them to do that.

MR. McCUOLLUM: Okay, I'd clarify that.

MR. McCARTIN: And I'd like to give maybe slightly different perspective on that And ultimately you end up with the design that DOE will contend is safe. How you got there is somewhat DOE's choice with the way they do the calculation, et cetera.

I think at the end of the day, certainly the NRC staff writing the rule, the technical people here, believe that at the end of the day the design that they have for the surface facilities is going to look fairly similar to a lot of similar activities all around the world. That I don't think you're going to Yucca Mountain and see, whoa, this looks so different than these kinds of activities in other places.

And at the end of the day we'll see what license application DOE submits, but I will submit that we have not been hearing from DOE. We're making this so different than anything else in the world. We haven't been hearing that.

And I know one can say, oh you're going to go to 3 g and you're going to have 10-foot thick walls, well, I think the license application will show you a facility, and I think maybe that's a way -- rather than looking at necessarily doing this risk calculation trying to compare the risks with a nuclear power plant, is the design here, does it look that much different than these other facilities around the world?

That will be a very interesting test.

MR. McCUOLLUM: And to date only one aspect of that design has been finalized; that aspect is the TAD aging overpack, and that was very very different.

VICE CHAIRMAN CROFF: So far - we had a briefing on the surface facilities. And the DOE is making every attempt not to have to lift anything. So they've got these very convoluted tipping things that just don't get anything off the ground more than what 12 inches or less. So it does affect the design, Tom.

MR. McCARTIN: Well, yes. But along the lines I talked about earlier. If I have this waste container, and it's pretty damn thick, pretty damn big. If I drop it two inches, what kind of dose am I going to see 11 kilometers away.

And if you're telling me I dropped this waste container a couple of inches, and I get greater than a 5 REM dose 11 kilometers away, well, maybe I do have to be pretty careful about that.

But that's the part that I will say at the NRC staff level, we understand what people are saying. But I will say, I have not seen the dose calculation that says dropping this completely intact container two inches would cause the kinds of consequences that the regulation is saying - that's the part of risk informed; they go hand in hand.

And I would like to see the full calculations to understand what the concern is. Because clearly if they are absolutely petrified of this thing dropping two inches, I'd like to see the full calculation to understand why.

MEMBER HINZE: Good point. It's ten minutes to closure here, and I would like to make certain that everyone has had a chance to have their say. So why don't we start with you then, sir.

CHAIRMAN RYAN: I guess the Devil is in the details. And without the analysis in front of us, we've circled the speculation now four or five times.

So there's lots of points of view and lots of inferences I think is the best way to put it on what it might look like. But there are important differences to think about.

I'd lie to make a comment. A lot of folks are talking about what the commission thinks, or what we've done, or who's done what. The commission gives us direction very formally and written direction. We make that into an action, and our charter, our action plan, is what we're here following through on today.

So that's the way our direction comes down from the commission. Our action plan called for us to have a working group on preclosure seismic activities without anything more specific than the prospectus that Bill put forward. So that's it.

I just want for the record for everybody to understand that we don't get directions from the commission in any other way than that formal process. So it's incorrect to speculate what they think, because we don't speculate on that. We simply collet technical information, and provide them our advice on that information.

MEMBER HINZE: That's an excellent point.

CHAIRMAN RYAN: Because there was a lot of conversation about that. I just wanted everybody to understand how the committee functions, and what our charter is, to collect and analyze scientific information and advise the commission therein.

But with that being said, it is interesting to think about a couple of key questions to me. Will this fuel handling facility look different than other fuel handling facilities as Dr. Kadak said exist around the world. I think that is an important question, and it'll be interesting to see how that works out in the LA. My sense is that it will be a lower inventory older fuel facility for quite awhile.

And with that being said, the potential

for a source term, given all the other things that make a source term, are about equal from any other accident kind fo analysis. It would be inherently lower risk.

So at the end of all of that, if we end up with a circumstance where a new set of requirements, or one of their directed regulation or in some analog document, or perceived requirements, or even decisions made to be deterministic or, quote, conservative, which I use the term loosely because it may not be conservative to overdesign - and again, that's my own term - a stronger, tighter, better, more robust facility. Is that a step in the right direction? That's an interesting question to think about at the end of our discussion.

So I think to me the take-away message I get is to be mindful that this has a potential to get it right, but there's also a potential to not get it so right if we take the wrong measures from the guidance we have and go forward.

So that's kind of the thing I'm thinking about going - I'm thinking that some of that, at least maybe with better words and more carefully constructed thoughts, needs to be in our letter relative to this white paper.

MEMBER HINZE: I would like to take a few moments and make certain that everyone has had their last comments made.

Raj, is there anything more that you'd like to summarize?

MR. NATARAJA: No, I think particularly if we keep saying the same thing again and again.

MEMBER HINZE: Yes, I think so too

MR. NATARAJA: We have said this before, and we have said it today again. Nothing much has changed.

MEMBER HINZE: And John, what's the message that we should take away from your presentation?

MR. STAMATAKOS: Well, I think it was just - I mean I viewed the presentation to address the comments we had received back about what aspects of 43-05 were precedent setting in the MOX review. And the notion was that that was just the first and very small example of applying a performance evaluation in licensing, with a very different purpose. It was a confirmatory on a different rule. And so I just wanted to make it clear what we relied on there. So when we refer to that in the ISG, what we really need.

MEMBER HINZE: Good show. Thank you.

I would like to call on the committee for any final remarks.

Dr. Clark?

MEMBER CLARKE: No thanks, Bill.

MEMBER HINZE: Dr. Weiner.

MEMBER WEINER: I'm still worried about one thing that was said generally. And that is I believe Raj and Mahendra said several times that you are going to look at facilities in Savannah River, Hanford, wherever. I would - we have had fuel handling facilities, and they've been handling nuclear fuel for close to half a century now. And there must be some actual experience that can be drawn from them that can play a role in this.

I mean our plants have been handling nuclear fuel also for that reason. And to what extent this devolves to seismic design I don't know, because I'm certainly not an expert there.

But I would just encourage you to connect this with the real experience that does exist and that has existed. Maybe there is no way to do it with seismic designs specifically, but there must be some connection. This is not a facility that is - whose function is unknown to us. And that's all I wanted o say. Thank you.

MR. NATARAJA: We agree.

CHAIRMAN RYAN: I am fine.

MEMBER HINZE: Mr. Croff, you had questions about risk and consequence. Have they been at least talked about?

VICE CHAIRMAN CROFF: They've been talked about.

MEMBER HINZE: Okay. With that, I'm going to toss the gavel back to Mike Ryan. But I would like to point out that the background paper which Mike Lee talked about this morning will be through internal NRC review by at least mid-November, and we would like to send that out and have some unfortunately some rather rapid comments back. And I would hope that everyone in this room would give us their sage advice on this background paper, which will be part of the letter that the committee writes to the commission, and which will be finalized according to plans at the December meeting.

Have I covered it, Mike?

MR. LEE: Yes.

MEMBER HINZE: It's yours.

CHAIRMAN RYAN: Thank you, Bill.

I want to first thank all of our participants today, both those who were around the table and those who have participated from the audience. It's always a much richer discussion for us when we get lots of views and perspectives. And I appreciate our colleagues from the tactical review board participating as well.

Thank you all.

One of the things we try and do in these more complicated and complex issues is to gather a range of views and opinions and points of view and reflect those as precisely and accurately as we can in our white paper so we give the commission a document that looks at the technical issues across the spectrum of opinions, and hopefully summarizes in our letter what our opinions might be about that body of evidence.

So your participation today really helps us meet our goals, and we really appreciate your hard work in preparing and coming and sharing your time and talents with us. Thank you all very much.

So with that, Bill, I think we'll close this working group session. And according to my agenda, we're off on a break until 3:00 p.m., and we'll reconvene with Allen Croff taking up the discussion of nuclear fuel recycling.

Thank you very much.

(Whereupon at 2:45 p.m. the

proceeding in the above-entitled matter went off the record to return on the record at 3:01 p.m.)

CHAIRMAN RYAN: Okay. Without further ado, I'll turn this remaining session for the day over to Allen Croff, our Cognizant Member for Fuel Recycling.

VICE CHAIRMAN CROFF: Thank you, Mike. By way of background, if the Committee will recall, we've had over a year ago some general background briefings on essentially aqueous reprocessing, and then we've had more recently since this last spring a couple of specific briefing on aqueous reprocessing from Areva, and from the folks at Energy Solutions. And that has all come together in the White Paper that I'm sure you've all come to know and love.

At this point, we're going to do something a little bit different and go away from aqueous reprocessing into, I'll call it non-aqueous at this point. And we're pleased to have two folks from the GE-Hitachi Nuclear Energy Company. First, Dr. Eric Loewen. He is the Manager of Advanced Plant New Product Introduction for General Electric nuclear business, and Dr. Earl Saito is the Manager of GNEP

Environmental Assessment for GE Energy Nuclear. They're both located in Wilmington, North Carolina at their facilities there, and they're going to talk to us about spent nuclear fuel recycling processes of the non-aqueous kind, so who goes first?

MR. LOEWEN: Okay. My name is Dr. Eric Loewen. I'm with GE-Hitachi Nuclear Energy, and I want to share with you our vision of how to commercialize -- close the nuclear fuel cycle.

MR. SAITO: I'm Earl Saito. I'm with GE-Hitachi, also. I have 10 years of background in fuel manufacturing, fuel fabrication, starting out with the combustion engineering site in Hematite, Missouri, and then with GE since 2000, working in both manufacturing and environmental health and safety, liabilities management and other roles.

MR. LOEWEN: Thanks, Earl. We wanted to give you kind of our one-slide view of what we think the Global Nuclear Energy Partnership is about, and that requires environmental performance, and operating performance. And to do that, we think that GNEP is a really a confluence or paths to forge the future in the sense that this all started in the Atoms for Peach speech in 1953. We, as a country, came up with the Integral Fast Reactor program, came up with a very good solution on how to go forward. That program was stopped. We started in Step 3, this Global Nuclear Energy Partnership, that we all -- came to light in February of 2006. And so what we think needs to be done is to build a model home on how to go forward with the process.

And this is -- the magic word for us is it's got to be a system. And we were asked to talk about one part of that system today, but we'd be happy to take questions about the rest of the system, so we view the system very briefly, is you take spent nuclear fuel in, you do a separations process, we separate into three different streams. The first stream is Uranium that can be used back into light water reactors with enrichment, or it can be used in the Can-Do reactor because of its enrichment.

The next stream is the actinide, which then becomes fuel for your fast reactor that produces electricity, and then your third stream is what we're here to talk to you today about, is that the fission products go into two different waste forms, metallic and ceramic. And those go to a geological repository.

The two components of the system, this is just one slide on the reactor so you kind of understand where we're coming out from the system standpoint, and that is the advanced, what we call the advanced recycling reactor, or better known as PRISM, which stands for Power Reaction Innovative Small Modular.

This was GE's start in 1981, when it realized the Clinch River Breeder Reactor Project was heading down the wrong direction technically, that it was trying to bail the 1,000 megawatt thermal plant and go to 3,000 megawatt thermal fast reactor. GE sat back and said should we make it smaller, more compact, modular, and that was in '81. But not to be at odds with the technical team at the time we waited; when the program stopped in '83, that's when we brought forth this design, and that's what got picked up in the nation's Advanced Liquid Metal Reactor Program from 1985 to 1995.

One of the things that came out of the program is what the Nuclear Regulatory Commission produced as NUREG 1368, which said that this has no obvious impediment to licensing, and this was under Part 50 at the time, when this -- we submitted as a Part 50.

The other half of this solution is the electro refining, or pyro processing, or electrochemisty. That really started in this country about 1964 with melt refining at Experimental Breeder Reactor 2, and we'll go into some of the history. And we look at that as a prudent place to start with looking at pyro processing, because it started in '64, and there's activity in the Integral Fast Reactor Program. In the '90s, Japan provided funding to the United States for the program, and it ended also in 1995, and so now we have the start of the GNEP Program, and it's a technology that we should use to go forward with.

So the big question is why is General Electric-Hitachi Nuclear Energy pursuing pyro processing, and we want to hit three high-level things, the environment, the economics, engineering of how we perceive the process.

If you look at this curve, and on these slides you'll notice I have a box where I call it ACNW&M WP, which stands for -- this came out of your White Paper, so I extracted these, and I thought it would be easier, since that's the discussion of the Committee, is to also put that into the talk. And so you've already talked about this as a Committee, and if you look at the very dark line that drops off at about 300 years, that's the fission products. And so if you take those actinides away, then you reduce the heat burden on the repository. And so we feel that heat becomes a limiting factor, rather than volume, if you take out human intrusion. So how do we get rid of the heat? Well, it's a net-zero game if you just separate those actinides and don't do anything with them. And so what we're saying is that we separate those actinides out, those long-life radionuclides and use that as a fuel for the fast reactor.

Why the dry process? General Electric in Wilmington, North Carolina manufactures fuel, and so we take uranium hexachloride in, and we produce fuel bundles that we sell to customers. Initially, when that plant was opened we had an aqueous process, where we converted the UF-6 into UO2 using aqueous process, and that led to a waste stream that we had to deal with.

We, as a company, decided that that was too much of an environmental risk. We spent a lot of our own money cleaning it up, and we do a dry conversion process now. And so when you look at reprocessing, now in the future, our Risk Council will not allow us to do a wet process. And so when we're looking at solutions, that's where we, again, revisited the dry process, and we think it will have a better environmental performance.

When we look at economics, we look at these two studies. And, yes, I know they're old, and they could be biased, but they provide a good reference point, and so the first study, the aqueous processing, was done by Oak Ridge National Laboratory, and they gave a clear-cut of how much you would need as far as a footprint of a building, the capital cost of facility to supply 1,400 megawatts electric to a fast reactor.

A similar study with the same sort of throughput was done by Argonne National Laboratory, proponents of pyro processing, and you could look at the bottom line number. You have about a factor of six difference, and so we feel because of that smaller footprint, you pour less concrete, have less components, that economically, this would be a better technology to go forward with.

When we look at engineering or proliferation, this is a slide that we use internally to talk about it. And if we look at the three signatures, if you will, of special nuclear material, that is the thermal power, the spontaneous neutrons, and the gamma radiation. In the case of weapons-grade Plutonium, for example, that would be at a facility like PANTEX, you can see what the watts, the neutron generation, and the gamma radiation is from the slide.

If you move to reactor grade Plutonium, that is taken out in a PUREX process, probably something similar to what's done at THOR or at La Hague, or soon in Japan, you can see that the thermal power is about the same, but you do get some more neutrons, and it's a little bit more easy to detect.

If you look at what pyro processing does, because it's not a pure separation process by design, because of the electrochemistry, you can see that the thermal power is very significant. The spontaneous neutrons are very significant, and, also, the gamma radiation. So if you have an overt sort of capture of the special nuclear material that came into the building, you would have the ability with detection systems to fly with a special plane to probably find it, because of this sort of signature. And so when we look at this engineering feature, it makes it very proliferation-resistant.

So I thought we'd walk through pyro processing, and first look at the inputs into the system. And the first input that goes into the system is the fuel bundle that you had in your White Paper of a boiling water reactor. And so, for the numbers that we use, or the gross composition, it's 95 percent uranium by weight, 4 percent of that is fission products, then 1 percent is transuranics. Transuranics are picking up the Neptunium, Plutonium, Americium and Curium.

The other input into the pyro processing system we showed in the first few slides is what the fast fuel bundle looks like. And so in the case of what we're looking at is a metal fuel, and that would be Uranium, Zirconium inside the metal fuel, and that would be the initial driver fuel to start up the reactor. We would move then to a Uranium, Plutonium, Zirconium. And then with lead test assemblies and fuel testing, finally eventually into a Zirconium Transuranic, or Zirconium Actinide fuel.

This is a block flow diagram that came from the White Paper, but it actually originally appeared in this report from the National Academy of Sciences, where they did an extensive six to seven year study of using pyro processing for the treatment of experiment Breeder Reactor Number 2 fuel. When Experimental Breeder Reaction Number 2 was shut down, much of that fuel had an enrichment, well over 30 percent Uranium 235, some close to 40 percent, and it was Sodium-bonded. And so that sort of fuel couldn't go into the waste stream, and that's what this

National Academy of Science Committee did, was look at it, is this the right way to treat that fuel? And that's the process that has been used at Argonne National Laboratory, now Idaho National Laboratory, since about 1996. And this graph provides the Committee kind of an overview of how much they've actually processed per year. So they're doing about 150 kilograms per year, pulling Uranium out, and then the -- all the actinides, all the fission products end up in either a metal waste form or a ceramic waste form.

So one of the things that we've looked at is kind of the history of pyro processing to see is this a very mature technology. And it really started from the mount refining in the beginning of how Experimental Breeder Reaction Number 2 wanted to operate. They wanted to show that they could use fast reactor fuel, because at the time as a Breeder Program, to show that they could get back up and running. And so, what they would do is take the spent fuel out of the reactor. They would put into a Zirconium oxide crucible, they'd heat it up to well over 1,200 degrees C, volatile fission products, no surprise, would come out and be caught in a fume trap. And then the other fission products, like Barium and

Strontium would react with the oxide of the Zirconium Oxide crucible, and make a skull. And then when they poured this out, they were left with the Plutonium that was still in the fuel. They did have the metals in there, and they would then cast that into fuel and put that back in the reactor. So this process, they could shut down, melt the fuel, and reload it. And the record was in 30 days, it was normally on a two-month cycle, and it worked reasonably well. They were doing 240 kilograms per month.

However, it had deficiencies. It had two large deficiencies. One is you had the noble metals that would -- fission products that would build up. And, eventually, if you went to higher and higher buildups or burn-ups of the fuel, you had the buildup of the noble fission products, and you don't have fuel in your reactor. And the process wouldn't be sustainable.

The second issue was that Mount Refining couldn't extract the Plutonium and actinides out of the blanket fuel. And that's when Argonne National Laboratory, during the Advanced Liquid Metal program looked at how we can improve that, and that's where the term "pyro processing" started. And this is about circa 1995.

So there's four key attributes of pyro processing that they started on. One is that all the actinides are recovered together, and that's because of the electrochemistry, so you can't take out pure Plutonium, you're not going to get pure Neptunium. You're going to get them all together, because the electrochemistries by nature happen to work out. It's ideally suited for a fast reactor, also, if you're going to use that either in a burner mode to burn actinides, or in a breeder mode to make actinides, or make Plutonium. And those are some internal reports that were done in the Advanced Liquid Metal program that looked at actinide burning. So these were some of the things that the program did in the final years of the Advanced Liquid Metal Reactor program.

The other two key attributes is it has no liquid organic waste, and it has no need for the spent nuclear fuel to have any storage period before you can actually start recycling.

CHAIRMAN RYAN: Just a question on that last one, if I may. Why would you want to do that?

MR. LOEWEN: Do?

CHAIRMAN RYAN: Recycle fresh fuel. I mean, that's a radiation protection question, I would guess, at least, all the noble gases, Iodine, all that.

MR. LOEWEN: We just present it, it's not a constraint, because we're saying we can take old or fresh fuel. When you're in a hot cell environment, yes, you would have more of those radioactive gases. In fact, in the design of the PRISM reactor, in the refueling, we take a third of the core out, and we actually keep it inside the reactor vessel. And that provides shielding to our intermediate heat exchanger, so we keep that in for cycle of 12 months, and then we pull it out, and then do the reprocessing. So you are right, that there is no -- in fact, in our design in the reactors, we're taking the fuel out, keeping it within the reactor vessel before we take it out and reprocess it.

MR. SAITO: But the benefit, though, is in a fast reactor. In the fast reactor part of the system, you don't have to hold the fuel for a long period of time, so you don't have to build as much storage.

CHAIRMAN RYAN: You still have a very hot fission product inventory, if you don't age it.

MR. LOEWEN: Correct.

CHAIRMAN RYAN: That is a different concern.

MR. SAITO: But you keep the fuel moving into the system, so you don't have -- so you'd have different storage issues. It's different engineering constraints, but we have an integrated system that would all be on one site, so you don't have transport issues.

CHAIRMAN RYAN: Okay.

MR. LOEWEN: So if we take a look at the flow sheet of what the components are, and some of the deficiencies within those components, this is the flow sheet that you also have in your White Paper. And this flow sheet is very difficult to explain to the public of what you're doing with pyro processing. And during the study of our facility that's located in Illinois, we had to have a public meeting to explain this process, and it was very difficult. So what I'm going to show you next is a clip that we use, an animation to explain pyro processing.

So this shows a spent fuel bundle, and then it gets chopped in a hot cell to recover the fission product gases. Goes into a basket, and then it's taken over a Lithium Chloride salt. It's about 500 degrees C, and submerged and voltage is applied on the order of about 4 volts. And you'll see the brown stuff on your left that's being taken out. That's the

Uranium metal, that would go into a barrel that could either be re-enriched, or go to a Can-Do Reactor. At the bottom, you're taking out the fission -- it's still up here.

CHAIRMAN RYAN: Stand by. It'll come back.

MR. LOEWEN: Still working on this one.

(Video problem.)

MR. LOEWEN: Should I start it?

CHAIRMAN RYAN: Why not?

MR. LOEWEN: Okay. This shows the fuel bundles chopped, goes into a basket. That basket is loaded into a Lithium Chloride salt, approximately 500 degrees C, a voltage is applied to the anodes and cathodes, and you get the migration of the Uranium metal to that electrode, and that's removed from the system. And that is used either in a Can-Do reactor or re-enrichment for light water reactors. The fission products come off in two different forms, and this animation we show just one, either ceramic or metallic waste form. The actinides, which include about 5 percent of a layer of lathanides, and about 25 percent Uranium, get then fabricated into fast reactor fuel in our system, and you would put that back to make electricity.

So what the issues for pyro processing? Though it's been proven well on fast reactor fuel, Experimental Breeder Reaction Number 1, is how do you use that outside fuel? Who has ever done that? Initially, during the Advanced Liquid Metal Reactor Program, they were going to use a chemical process where they used Lithium reduction, so you had Lithium metal, they took the oxygen away from the Uranium, the Uranium then went into the processing.

What was developed after the Advanced Liquid Metal Reactor program was the electro reduction, so now you put in the Uranium oxide into a bath, as we show in the animation, apply electricity and get a reduction. And this is similar to what is done in the aluminum industry, where they have an oxide named Bauxite, and that ore where they add electricity and they do that reduction, where they end up with aluminum metal. And so Dr. Saito and I had the opportunity to tour one of those smelters in the United States, and got to see the high-end of a commercial process that uses electro refining.

So what we presented at the RIC conference, and we also submitted to the Department of Energy was the idea, let's do a demonstration. Let's take the Uranium that we have in Wilmington, North Carolina under our Part 70 license, and get an electro reducer from the National Laboratories, and do a joint demonstration to show that this -- to prove the technology works on a commercial scale. So if you get enough Ph.D.s in the room, you can get anything to work, but when you put it into a manufacturing community, when you're running the thing and trying to get the economics, that's where you can really fully test the viability of the technology. So we submitted that proposal, and we've talked about it at the RIC conference, and we also talked about how we license that at our facility.

And the idea is to take the fuel pellets that are shown in the picture here, put them in the bath, and end up with Uranium metal. Then those you put in surrogate materials for the fission products, and then extend that to get some idea of how this process works, so that we can understand it better.

So if you do that head-end step, or the electro reduction of metal, then you take that and put it into what's called the electro refiner. And this is the apparatus that's been well-documented, and studies in the National Academy of Sciences. It actually has two electrodes. The first time you turn this on, you move the Uranium, and that's what you take out of the system. And it has a liquid Cadmium electrode, and that's where all the actinides go, and you take that out.

Now this is work that Argonne National Laboratories had done. This pyro community is alive and well, and this example for the Committee is the International Pyro Processing Research Conference that was held at Idaho National Laboratory in August of 2006, shows a lot of activity around the world. For example, Korea has taken this design, and has made it continuous, where they have gravity separation, and they use an auger to take it out. The Japanese have taken the design and made, instead of cylinder, plain, and those plain electrodes have scrapers, so it runs continuous, and they extract that Uranium, Uranium and/or the actinides out. So there's been a lot of work internationally done trying to improve this electro refiner to make it more of a continuous operation.

The next part of the step in the flow sheet is the cathode processor. When you extract the actinides out of the bath, you're going to have salts that are either included within that mass, or stuck to the side, and so you need to get those salts off. It's a simple process of boiling to where the Lithium

Chloride and Potassium Chloride boil off, and now you collect that metal. And that's the actinide metal that you next take to the next process, which is this injection cast furnace.

So when you look at making an oxide fuel at our Wilmington facility, when we make Uranium oxide, we have to do a lot of braining steps, machining, all those sort of things to look at how the fuel is made, and we don't have to worry about high radiation doses. So if you did that sort of process for an actinide fuel, and you wanted to make it an oxide to put in a fast reactor, all that would have to be done remotely. And so we would, if the Chairman would like, we would love to have the Committee down to our fuel fabrication facility in Wilmington, North Carolina, and you can see how we make fuel.

Now imagine if you added Plutonium, and you put that in a glove box, is one thing, but now take it to the next step, and you take all the actinides with you, and you have the huge radiation dose. How do you put that all in a hot cell? And I think after touring our facility, you'd see that would be a very difficult and a very expensive way to do it. So with the metal fuel, if you look at this whole system again, this metal fuel is very easy to cast. You have it in a heated crucible, and you just, essentially like a straw, suck it up into these glass tubes.

The specification doesn't have to be that rigid because you're putting in cladding that you're 75 percent of the diameter, because metal fuel swells a lot. So you're going 75 percent of the diameter, sticking that into your cladding, and starting up. And then as it swells, you don't that pellet fuel cladding interaction, and so that's why, again, looking at the system, that we think a metal fuel is easier to fabricate when you start going into a hot cell.

Then the last component of the flow sheet was, what do you do with the waste components? And this is, for the noble metals, where you take the Zirconium from your light water spent fuel, add some Iron, put some Copper in there, and you make a metallic ingot that's corrosion-resistant. So the issues with Technetium being in the environment as oxide is very mobile. You take that out of the equation, because now you have Technetium as an allow within this metallic fuel.

So let's talk about the product streams that come out of pyro processing. Most of the fission products -

MEMBER HINZE: Are there scales on these at all? Trying to get some visualization.

MR. LOEWEN: Scales?

MEMBER HINZE: How large are we talking about?

MR. LOEWEN: This electro refiner, this one here, the -- well, let's go back to that. So the question is how big is the electro refiner, order of scales. The bath would be below this table here and fit in the center of the room right in here, and then that top part would fit below, so that thing would fit in the -

MEMBER HINZE: So a couple of meters across, something like that.

MR. LOEWEN: Yes.

MEMBER HINZE: Okay. All right. Thank you.

MR. LOEWEN: So all of these components, so if we go to the beginning, electro reducer, which I don't have a picture of, this electro refiner, cathode processor, and then this injection cast furnace. If you went out to Argonne National Laboratory, it would all fit in a room this size.

Dr. Saito and I were also in Korea last week, in two of their facilities. What they're doing in pyro processing, and they have some hot cells no bigger than this room, also, with this sort of equipment in there. So it's not that big, and that's part of -- back to the original slide that I showed you on the cost comparison, when you look at aqueous process versus pyro process, you see it has a reduced footprint of concrete just because it's different sort of components.

MEMBER HINZE: Sorry to interrupt.

MR. LOEWEN: That's fine. So product streams, the first one is fission products. Most fission products like to form a stable chloride, so they end up in that first reduction step when we're doing the light water oxide reduction. And you'll get those there, specifically Cesium and Strontium. Those you pull out of the waste stream. The other one is the noble metal fission products. Those remain in the bath, and when they accumulate to some level, that's when you take those noble metals out. The actinides are what you're trying to capture, because you're trying to get those out of the waste stream, and those are what we then fabricate into the fuel.

This metal waste form got a significant amount of attention in the National Academy of Sciences view of how they're going to get rid of the waste stream, and so there's a lot of different formulations when I look at the literature on what sort of alloy should it be, should it have a lot of Copper, should it have more Iron, should they have more Zirconium? And so that's something that we need to look at, is what is a performance criteria that we're trying to do, long-term? What corrosion level are we trying to do for this waste form?

This is just one of the phase diagrams. This looks at Iron Zirconium, and it turns out with the Zirconium that you're getting from the spent nuclear fuel from the light water reactors, it actually makes a nice eutectic on the -- 20 to 30 percent loading of the Zirconium in there to where your melting point goes down to about 1,300 degrees C.

On the other end is a ceramic waste form, and what happens there is that you take this salt, and you run it through Zeolite, which is nothing more than a mineral, and that's where you're picking up those fission products, and capturing them. And then when you have those captured in the Zeolite, then you form it into a ceramic matrix, or you could put it into a glass. So that's the formulation, when you look in the literatures, there's different sort of approaches. In Korea, they're looking at a calceous silica phosphate glass. United States, you look at what

Savannah River is doing, it's a boric silicate glass. You could also look at calcium silicate. Again, that's another performance standard; what do we want to build this waste form, and what sort of resistance would we want to have in it?

The next picture shows a figure of the Zeolites. And the design for the commercial plant that we envision would produce a waste form that would be about 30 inches diameter, about 6 feet tall. And at the time it was designed, what they are trying to go for is a waste loading of less than 1 kilowatt per meter in the repository. And so with the waste package that was about 4 kilowatts per waste package is what you had to do. So they would load the waste into that ceramic at about 6 watts per package, and that would go into the pool that's at the processing facility and sit there for about 10 years, until it gets less than 4 watts per package. So that was kind of the design-basis of how we do the waste. So you initially load a little bit more of the heat, short-term heat load into it, that would eventually leave the facility and go into a geologic repository.

This is just a brief slide on the National Energy Policy of 2001, that recognized that pyro processing should one of the technologies that should be included. We think we should, as a country, lead with pyro processing, and we can always, if we choose later to buy an aqueous technology from overseas, we have that opportunity. But this is really a technology that our National Labs developed from 1985 to 1995, that GE is looking to commercialize, similar to what General Electric did when it commercialized boiling water reactors from the National Laboratories in the early 50s.

To show you a little bit of the work that's been done at our nation's National Laboratories, this was a concept to, how do you process 100 metric tons of spent nuclear fuel from light water reactors? Argonne National Laboratory did this work, and they provided these slides to us. This is a birds-eye view of what the plant looks like. They also did significant amount of modeling internally. I don't have the video clip to this, but they have an animation that shows how we would go from an electro reducer, to electro refiner, to a cathode processor, the injection casting into the waste product. There's a view from the floor, so that work has been done.

Also, what the GE team did back in the Advanced Liquid Metal Reactor program, is this report to look at to build a facility. Now this one we did a little bit more of an extensive look, that we actually designed four different facilities. One was a centralized fuel facility that only processed fast reactor fuel, that's number one. Number two was a co-located facility at 22 metric tons per year that would support just one plant, or one what we call power block. Then we had a very, very large facility, number three, which is a central facility that just did light water reactor fuel, and it would process on the order of about 22,000 metric tons of Uranium per year, and then it would ship that fast reactor fuel that it fabricates off to fast reactors. And then the fourth one was kind of a hybrid of all of them. That was to support a plant that had three PRISM power blocks, for a total of 1,866 megawatts electric on the grid. And, initially, it could do up to 900 metric tons of Uranium oxide per year, and then when it got to steady state, it would do on the order of about 50 metric tons of liquid metal fuel.

And this is the design at that particular plant. I'll point out two features to the Committee. On the far right-hand side, you see what is dry storage. That's where the spent fuel comes from the PRISM reactor, and that's air-cooled. Then there's sodium removed, and that goes into the processing plant. Then on the other side is we have the pool, and that pool is used to take in the spent fuel from the light water reactors. And it's also used for the storage of the two waste forms that we generate, both the ceramic and metallic, to verify that they're less in their heat generation rate before they would be moved to a repository.

Here's a side view of the similar plant. You can see the spent fuel pool. There's a considerable amount of design work that was done on this. And one of the things they looked at was the waste processing. Again, there was three big streams, the fission gas collection. Because this is done in a hot cell in an inert environment, it's very easy to cryogenically separate and remove the fission product gases to compress those, and to store those, and to allow those to decay. We also had the metal waste that comes out in the ceramic waste. And this plant, based on the throughputs I had in the previous slide, initially when it starts up is going to generate about 191 canisters of ceramic waste forms a year, and going to generate on the order of 121 metallic waste forms, initially as it's consuming that light water reactor spent fuel, to produce the start-up cores for the PRISM reactor.

So how do we go forward? I mean, we have two schools in the nation that produce criticality engineers, the University of New Mexico, and the University of Tennessee. So how do we start again to do -- to license this sort of a processing plant? And so our vision, and this is what we presented at the NRC Regulatory Information conference, is it's really three steps. It's licensing, it's simulation, and it's component testing, and so our view is that we take this electro reducer that we would get from a national laboratory, get their design, and we would license that under our Part 70, using a risk-informed approach with Part H, with the Integrated Safety Analysis, and start that up to show that it would work. We would use surrogates for the fission products to see what sort of contaminant level, what do they do to viscosity, what do they do to the electro resistance and all those different variables, and then you have a component that's tested, that you could then deploy if you wanted to start using that for spent nuclear fuel at a different site.

In that process, we would be able to show our material control and accountability with the pyro process, and this kind of outlines how we would do the sequence of doing this licensing plan. And so one of the steps that we have in there, Chairman, is to report those results back to this Committee, so you would have a facility, you would have something running. It would have an NRC license, and we would come back and say here's how our electro reducer works. After you get done with that, then you do an electro refiner, and come back and see here's how the electro refiner works, then a cathode processor, then injection casting. And so, at that point, you have the ability to look at a system component-by-component, incrementally, as we all gain experience in licensing, and in operation, and in the economics, that then that third bullet down, is you then deploy that with spent nuclear fuel at some facility.

And so I close with this slide. We want to thank the Committee for allowing us to present, and we think we've presented what we think is an integrated solution using two technologies that were developed in the United States, that are ready for commercialization by industry. And we also have a site, that we didn't talk about. We also have a facility in Illinois that could be a potential site that would save some money as far as licensing process, get the spent fuel. So with that, I'll turn it over to the Chairman for questions.

VICE CHAIRMAN CROFF: It comes back to me, I guess, for a little while. I think it's time for some questions. Dr. Hinze.

MR. LOEWEN: And we were warned several times that we had to finish in an hour, so -

VICE CHAIRMAN CROFF: And I appreciate it.

MR. LOEWEN: It was 45 minutes in the -

VICE CHAIRMAN CROFF: Very lucid, well within the time limit. I do appreciate that.

MEMBER HINZE: Did I understand that pyro processing is going on in Korea, Japan, or some -- where is it going on?

MR. LOEWEN: Yes, sir. The question is where is pyro processing going on? Initially, the technology was developed at Argonne National Laboratory both East and West, part that's now part of the Idaho National Laboratory early 1985.

Japan then provided funding to the National Labs to start that in the mid-80s, and they have a lot of activity with a place called Kreppe, is where they do the research. And both Dr. Saito and I have been there at two of their facilities.

Korea was a little bit later, and they started doing pyro processing because they're not allowed to do aqueous processing on the peninsula.

And so they saw this as really their only technology they could start looking at to closing the fuel cycle. And they're kind of unique, because they do have Can-Do Reactors, and so they've looked at the DUPIC process where they take PWR fuel, volatilize it, and put it into a Can-Do, or they could use this pyro processing to extract the Uranium to put it back into their Can-Do Reactors.

If you look at this conference proceedings, you see activity in Russia. They're doing electro-reducing where they don't go all the way to a metal. They extract it as Uranium oxide, so they don't drive the potential quite as hard. So there is activity in the world with pyro processing.

MEMBER HINZE: What will you achieve from your test facilities in South Carolina that you're trying to develop, that you can't get from these other facilities?

MR. LOEWEN: Okay. The -

MR. SAITO: You'll get licensing experience. What these -- these other -

MR. LOEWEN: We trying to move towards commercialization.

MR. SAITO: Yes. We're trying to move towards a commercialization process. In order to commercialize it, we need to be able to get through the Integrated Safety Analysis, be able to demonstrate safety to the NRC. And, so, if we come with a big plant at the end of the day, if you develop this all in the National Labs, and then walk into the NRC office and drop down the whole plant and say license this, it's going to be very difficult. So it's a step-wise process to get us through the licensing to operation. Not that we have anything that's superior to the National Labs, but it's the path to commercialization.

MEMBER HINZE: So this isn't technically-oriented, it's regulatory-oriented -

MR. SAITO: And commercially-oriented.

MEMBER HINZE: What does your waste look like in terms of the volume of the input, volume-wise? What's the volume of the waste in comparison to the volume of the input?

MR. LOEWEN: Based on this report, it's on the order of 50 percent. So you're going to have 50 percent reduction in the waste, so you take a spent fuel bundle, and then if you look at the ceramic waste form, and the metallic waste form coming out, you're going to have about a 50 percent waste reduction.

MEMBER HINZE: And no fluids that have to be put into a glass form, or any of that sort of thing?

MR. LOEWEN: No fluids.

MEMBER HINZE: They're ceramic.

MR. LOEWEN: So that's why we call this a dry process, because all your fluids -- you have liquid salts because you're at temperature. So if you lose that temperature, you're solid. And so that's attractive to us. We did aqueous processing, or aqueous conversion in Wilmington, North Carolina, and we, as a company, won't do that again, because of our risk profile.

MEMBER HINZE: Thank you very much.

CHAIRMAN RYAN: Morris, Illinois is what you're talking about in Morris. Correct? Yes. Okay.

MR. LOEWEN: Located next to the City of Morris, Illinois.

CHAIRMAN RYAN: Right. You almost did liquid processing there, I guess, years ago, somebody did.

MR. LOEWEN: Well, that processing was flourinization, so the idea was, we took a chemical process that we used fluorine to volatilize the Uranium and extract it off. And when you scale a chemical process, you've got thermal dynamics, kinetics, and mass transfer, and in that scaling process there are some difficulties technically, and it didn't run. And when President Carter said we're not going to reprocess, and we're having difficulties, it was an easy decision to say we're not going to do that.

CHAIRMAN RYAN: That ended that. Sure. One of the waste questions that I always like to ask is, the devil is in the details. We have a two-tiered waste system in the United States at the moment, low-level waste, high-level waste, and then a couple of strange little categories in the middle of greater than Class C at TRU, at least in the commercial side. How do your waste -- you've got two wastes, as I'm hearing you say, are they both high-level waste?

MR. LOEWEN: Yes.

CHAIRMAN RYAN: And there's no low-level waste? There's got to be some.

MR. LOEWEN: There is some.

MR. SAITO: Operational low-level waste.

CHAIRMAN RYAN: There's operational low-level waste. But the devil is in the details there of how much is Class C, Class A, Class B, greater than Class C, TRU? And is it in any way a mixed waste, because of the metal content, and those kinds of things? I really focus on the details of all that, because I'm always questioning whether or not a new process will create wastes that don't have a home. That's really my question.

MR. SAITO: Leachability is your biggest concern, and that's what drives characteristic waste in EPA.

CHAIRMAN RYAN: Right.

MR. SAITO: So both of these forms are going to be -- the key to both the ceramic and the metallic form is to have a very low leachability. So we should not see any mixed waste coming out of this.

CHAIRMAN RYAN: Did not or do not?

MR. SAITO: Well -

CHAIRMAN RYAN: That's still to be determined.

MR. SAITO: You have to finish the job, but the fundamental law that is you're not going to see it. We're not adding any -- well, there's some Cadmium in the system that will have to bound up, but that's not going to be -- other than the Cadmium, you're not adding anything that could become a mixed waste. You don't have the organics, where you could get organic problems, so you don't have volatility from flammability, so you don't have procivity, you don't have ignitability, you have -- the only RCRA metals that you have -- the only thing you have to worry about is the RCRA metals.

CHAIRMAN RYAN: Right. There's a whole suite of those, but that's -- I mean, you only need one to make a mix.

MR. SAITO: Correct. But that's a low probability of occurring with the process the way we're running it, because you'd have to fail TCLP with it, not that your total metal may be higher, but your TCLP will definitely not be an issue.

CHAIRMAN RYAN: Well, it hasn't been tested yet, so, hopefully, it's not an issue.

MR. SAITO: Well, I've moved a lot of waste, and this is -

CHAIRMAN RYAN: So it hasn't been an issue so far.

MR. SAITO: Yes.

CHAIRMAN RYAN: Okay. That's good.

MR. LOEWEN: And that was one of the concerns of the National Academy of Sciences, when they looked at that using that technology for processing the EBR-II fuel.

CHAIRMAN RYAN: You have used this process in other countries?

MR. LOEWEN: We have. General Electric has not, but it has been used in Japan.

CHAIRMAN RYAN: It has been used in Japan. Okay. In Japan, they have a multi-tiered system. Does their waste end up as just low and high, or do they have intermediate level waste generated from this process?

MR. SAITO: They don't have a disposal site right now, so that's all an academic discussion.

CHAIRMAN RYAN: Yes. They still have the categories of waste, though.

MR. SAITO: Well, I was responsible for the GNF Plant in Japan. They don't have a waste disposal facility -

CHAIRMAN RYAN: High-level waste. They do have a low and intermediate they're developing now at Rokacho.

MR. SAITO: Potentially, they do. We haven't been able to get anything into it. I mean, it's an academic -

CHAIRMAN RYAN: Low-level waste exists.

MR. SAITO: I'll discuss that with you afterwards, if you'd like.

CHAIRMAN RYAN: I've been there. I've seen it. They're putting waste in the concrete -

MR. SAITO: And I've run a facility there, and I have a building full. I'll just -

CHAIRMAN RYAN: Okay.

CHAIRMAN SMITH:

MR. SAITO: I can discuss it with you afterwards.

CHAIRMAN RYAN: But I guess what I'm trying to get at here is that, my basic question is, in the United States, how do we know that this process will generate waste that have an acceptable home for disposal?

MR. LOEWEN: I think you have the backdrop of the National Academy of Sciences that look at this process for six years, and said this is a good way to go for the EBR-II fuel.

CHAIRMAN RYAN: That's not my question. My question is, does the current regulatory framework in the United States have a home for every waste you generate?

MR. LOEWEN: Yes.

CHAIRMAN RYAN: Okay.

MR. LOEWEN: I'll put the caveat on that, that we plan on using the Uranium as a product, so some of the waste rules will have to be changed, so that that's no longer considered waste. It comes back into a product stream.

CHAIRMAN RYAN: Fair enough. All right. How about the high-level waste, where is that going to go?

MR. LOEWEN: It's high-level waste still.

CHAIRMAN RYAN: Is it acceptable at Yucca Mountain? Is it within the definition of what can go there?

MR. LOEWEN: Okay. Well, then I will add the caveat, as does the Waste Acceptance Criteria need to be changed at Yucca Mountain?

CHAIRMAN RYAN: Yes, is the answer.

MR. LOEWEN: And the answer would be yes.

CHAIRMAN RYAN: And then the other is, some of the mixed waste, and low, and greater than Class C waste that would be generated under normal operating circumstances.

MR. LOEWEN: And those are part of the reasons why we want to do that demonstration in Wilmington, to look at what are the sort of carry overs, how frequently do you have crucibles, what sort of adhesion do you have with the crucible?

CHAIRMAN RYAN: Now you're on the page I'm on, the normal operating waste could generate wastes that are in categories that currently don't have a home.

MR. LOEWEN: And that's why we want to do a demonstration -

CHAIRMAN RYAN: That's a possibility. Okay.

MR. LOEWEN: -- under Part 70.

CHAIRMAN RYAN: Fair enough. But, to me, it's generally the case, is the process is great on the front end, but the waste that you generate sometimes cause impacts on the process, and sometimes it's occurred that the process fails because the waste that you have to find a home for, make the process too hard to do, or too expensive, or one of those things. So that's your challenge, I guess, I see moving forward, is that this really has to be vetted with regard to the process and its intrinsic merits, but also with whatever waste it produces, have to find a home, or it has a potential negative impact on the process itself.

MR. LOEWEN: But from a high-level, to me, it seems comfortable, because you're taking -- you're putting elements in a waste form that they like. So many of the fission products that are lower in atomic number that like form in salts, that are easy to put in a glass form, you're doing that. The elements that you want to keep, and all the metals that really don't like to be in a boric silicate glass, you putting those into a metal form. So you're putting them into forms that -

MR. SAITO: But you are correct, 80 percent of our waste cost now is from 2 percent off-site condition in our current operating plants. All our fuel plants, that's what costs us money. It's not the normal operations, it's the off-site condition, recovering from off-site conditions.

CHAIRMAN RYAN: Now you're on the page I'm on.

MR. SAITO: I completely agree with you. That's the reason we want to go to an operating plant, run it, see what those off-site conditions are, see what happens.

CHAIRMAN RYAN: And that's -- the devil is in those details. It will make or break the process, usually does.

MR. SAITO: Yes.

CHAIRMAN RYAN: By the way, your wet processing friends have the same troubles.

MR. SAITO: And that's why we -

CHAIRMAN RYAN: Maybe more so. Who knows.

MR. SAITO: We used to run an aqueous separations recovery, and we stopped running that because of that exact issue. It would run beautifully, and then you have a small upset. You've generated thousands of gallons of something you have to reprocess, takes you 20, 30 times the amount of time it took you originally.

CHAIRMAN RYAN: And it impacts the economics, as well as the waste disposal questions, which is at its root an economic one, too, but it's also, what do I do with it? If I don't have a home, I'm sort of stuck. This clearly has a lot of advantages of not producing a lot of different kinds of waste, but I think it's still a good question. I think that's enough.

VICE CHAIRMAN CROFF: Okay. Ruth.

MEMBER WEINER: Well, I was very glad to see that the EBW-II process has been -- has surfaced, and that you're actually using a variant of it to treat waste, because I always thought that was a neat kind of process. So my question is, at the time that the EBW-II waste was being generated with all the actinides in the metal form, and the fission products in salt, there was some discussion of changing the criteria for disposal in the WIP, getting rid of the fact that it had to be Defense-generated, because that actinide waste, the true waste that you have could go into the WIP, except that it's not Defense-generated.

Has anything happened with that? Have you looked at that at all?

MR. LOEWEN: I haven't looked at that.

MEMBER WEINER: Because I believe there is a path there that ought to be investigated. It's not that -- you're not going to get that big a volume, and with respect to the Waste Acceptance Criteria, it meets the WIP Waste Acceptance Criteria quite handily. That's what the WIP was designed for, really.

The other question is, how do you get from the melted salt where you have the fission products to a ceramic form? Did I miss that?

MR. LOEWEN: Well, it's -

MR. SAITO: Just real quickly, while he's looking it up to answer your first question, went to a meeting where all the sites were together, and the Hobbes, New Mexico site did point out what you were talking about. And, certainly, it sparked out interest, something that gives the Hobbes site a great advantage, and certainly makes it an attractive site to look at doing some of these things at.

MEMBER WEINER: I think one of the things you've had to look at is the volume that you're producing, because there is a limit to the volume, to the WIP volume. But it seems to me that at least some certainly meets their criteria.

Okay. I see where you -- okay.

MR. LOEWEN: So you're taking the salt, it goes through that Zeolite. And then you're taking that Zeolite, you're adding the glass frit. Depending on what chemistry glass you're trying to achieve, and then that's where you do that hot-centered press.

MEMBER WEINER: And then you get, basically, a ceramic form.

MR. LOEWEN: Ceramic or sin rock, depends on which genre of waste -

MEMBER WEINER: Why can't you store that, since you've got just fission products in there, you've got rid of your actinides, why can't that be stored in some kind of long-term surface storage?

MR. SAITO: Commercially, we wouldn't want to store it in our facility. We don't want to become a waste storage facility.

MEMBER WEINER: No, I understand that.

MR. SAITO: So if there was -- if that was the national policy, that certainly would be an attractive national policy.

MEMBER WEINER: Well, I wondered if that was anything that you had considered pursuing, because it seems to me, one of the advantages of separating out the fission products is that, because of the short half-life, they don't absolutely require mined geologic storage.

MR. LOEWEN: Correct. But there's going to be some very amount of actinides, and so how do you redefine the Waste Acceptance Criteria?

CHAIRMAN RYAN: And that's the devil I'm talking about.

MR. LOEWEN: That's right.

CHAIRMAN RYAN: Because that fraction going each way could make it all the same waste.

MR. LOEWEN: And the way this was planned commercially was, we viewed this as putting this into a repository. You would have that ceramic waste form, and metallic waste form, you're still doing a waste reduction, and you're generating -- you're covering the cost of this process by making the electricity from that 1 percent of the actinides that's in the light water reactor fuel. So it's not a -- it's a system that pays for itself by making the electricity, and you get two stable waste forms that would go to a repository.

MEMBER WEINER: Okay.

MR. LOEWEN: If you want to keep it above ground, that's fine, but we would not choose to do that on our property.

MEMBER WEINER: Yes. I see what you're saying, where the detail is, that you would have to -- that would raise some question.

Finally, if at some future time we start to re-think the whole posture because, after all, we have proliferation of Plutonium all over the world. I mean, it's nice that you track the Plutonium. Could you alter the process so that all of the fissile actinide content could be reused as a fuel?

MR. SAITO: It is.

MR. LOEWEN: Well, that's how we're running the system.

MEMBER WEINER: That's how you're running, so you -

mR. LOEWEN: So we're taking all the fissile-

MEMBER WEINER: You take all the fissile out, and -

mR. LOEWEN: Yes. And this is in the backup slides, is this -

MEMBER WEINER: Oh, okay.

MR. LOEWEN: -- the electro negativities of the separation, so you're pulling that -- from this slide, you're seeing the free energies formation.

MEMBER WEINER: Okay.

MR. LOEWEN: And so you're pulling out the Plutonium, Americium, Neptunium and Uranium together. You can't get them separated. And so when we look at, since this technology was developed in the United States with some sort of approval that I'm not aware of, I don't know how it occurred, but you have it in Japan, and in South Korea. And so I think, not speaking for the Department of State, that I think they would feel more comfortable about this sort of technology, doing separations, than other sort of technologies. Because this is -- nature is constant. I mean, you're not going to -

MEMBER WEINER: Okay. Thank you. Thank you, by the way, for a very good presentation.

MR. LOEWEN: You're welcome.

VICE CHAIRMAN CROFF: Jim?

MEMBER CLARKE: Thank you. I have a few basic questions. And if I understood you correctly, your fast reactor piece could be used as what I guess GNEP is calling an advanced burner reactor, where you'd use the actinide stream as fuel. You could also use it as a breeder reactor. Would you use the Uranium with that? I mean, do you have -

mR. LOEWEN: Yes, sir. A fast reactor is

really a material balance sort of reactor. And if you load a heterogenous core with Uranium as a blanket, you will breed Plutonium. If you load it as a homogeneous core, where you put the same sort of fuel, it will serve as an actinide consumer. And for our system to be a solution for the spent nuclear fuel in this country, we would run that as an actinide consumer.

MEMBER CLARKE: Okay.

MR. LOEWEN: So it would be a homogenous core. You would use some of that Uranium you recover, because we're running a Uranium Zirconium Transuranic fuel, but we're not putting that Uranium by itself in a blanket to make more Plutonium.

MEMBER CLARKE: Okay. What happens to the actinide when you use it as a -- the actinides when you use them as a shield in a burner reactor? What are you left with as a spent fuel after you do that?

MR. LOEWEN: The actinide in a fast reactor fissions and produce heat, and it makes fission products, just like the Uranium did.

MEMBER CLARKE: Aren't you still left with a spent fuel?

MR. LOEWEN: Yes. So then you take the spent fuel from the fast reactor, and you put that back into the same -

MEMBER CLARKE: You would separate that as, well.

MR. LOEWEN: Same reprocessing plant. And you take one step away, you don't have to do the electro reduction of the oxide to the metal. You just stick it into the electro refiner, and do the separation. So at that point, this plant kind of to use the analogy, becomes a kidney. It's removing fission products. It's bleeding in fissile material from the light water reactor, making fuel again and sticking it back into the fast reactor. So that's part of the system, the full system.

MEMBER CLARKE: Okay. And you're still generating the same kinds of waste streams when you do that.

MR. LOEWEN: That's correct. So you're still making -- you still have fission products, and those fission products have different properties, and so the ones that like to be a ceramic, we put them in a ceramic. The ones that like to be in a metal form, we put those -- the noble metals, we put those in a metal form.

MEMBER CLARKE: Okay. Just, I guess, one other question. What are the energy requirements of this? And have you looked at putting this piece into a fuel cycle, and a whole kind of life cycle analysis?

MR. SAITO: Well, we've looked at this - Eric has the exact numbers, but the analogy I use is that the aluminum industry does this for dollars a pound. We're going to do a similar process, so it's going to be on the dollars per -- couple of dollars per kilogram scale. When you look at the cost of reprocessing, couple of dollars per kilogram is very low. I mean, people talk about it being a very high-energy cost, but it's very high-energy cost for something like aluminum, which has a limited value to start with. When you compare it to the value of Uranium at hundreds of thousands of dollars a kilogram for enriched Uranium, it's actually a very low-energy cost.

MEMBER CLARKE: Plus, I guess, when you run the actinides as fuel, either in a burner reactor or a breeder reactor, you're running those as power reactors, as well.

MR. SAITO: Right.

MEMBER CLARKE: Is that right? So your fast reactor is also going to be used to generate power.

MR. LOEWEN: Yes.

MEMBER CLARKE: I just wondered if anyone had just kind of put it all together, and looked at energy in, energy out, all the other -

MR. SAITO: Yes. We have those exact numbers, where Argonne had come up with the watts per kilogram produced. But I look at it from the big economics picture, and the big economics picture, it's a couple of dollars a kilogram, so it's not substantial, compared to capital cost.

MEMBER CLARKE: Okay. Thank you.

VICE CHAIRMAN CROFF: It's marvelous to have time for questions.

MR. LOEWEN: We listen to the Chairman.

VICE CHAIRMAN CROFF: Thank you. I'm going to -- I take you all over the map, I'm afraid. I think the first, you showed in response to one of the questions, a diagram, one of the color cartoons of electro refiner, or the pyro processing flow sheet. Is that the current -- I know it's a cartoon, but is that your current process? I mean, that's essentially it?

MR. SAITO: No, that one has the reduction.

MR. LOEWEN: Yes, with the exception of, we would do electro reduction, rather than this oxide -- see the oxide reduction box?

VICE CHAIRMAN CROFF: Yes.

MR. LOEWEN: This is used in Lithium oxide reduction.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: So this hasn't been updated to reflect the electro reducer step.

VICE CHAIRMAN CROFF: Okay. On EBR-II, is EBR-II fuel still being processed?

MR. LOEWEN: Yes, sir.

VICE CHAIRMAN CROFF: Still working that off. And I thought I heard you mention something about you couldn't do the blankets.

MR. LOEWEN: You couldn't do the blankets with electro refining.

VICE CHAIRMAN CROFF: Well, why?

MR. SAITO: No, with metal-metal. You couldn't do it with metal. You can do it with electro -- with -

mR. LOEWEN: The electro reducer. The early stages of EBR-II, they were just melding it in the crucible.

VICE CHAIRMAN CROFF: Right.

MR. LOEWEN: So the reason why you couldn't do that with the blanket, is you couldn't pull out the Plutonium, because you're trying to make a breeder, so you're trying to separate the Plutonium. So when you melt that fuel, the Uranium and the Plutonium just are together.

VICE CHAIRMAN CROFF: Oh, I see.

MR. LOEWEN: So that's why you couldn't use it to separate the Plutonium out for melt refining in this crucible.

VICE CHAIRMAN CROFF: Okay. But you're using the electro refining process on blanket fuel now, or they are at -

mR. LOEWEN: Yes. That's where -- the words kind of get -- melt refining, think of it just as a crucible, and you're just loading fuel, and you're heating it up. And then you're decanting what's left off of it.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: Electro refining is where you have that box that would fit in the center of the room. You have electrodes, two of them, one to move the Uranium out, and then the liquid Cadmium electrode to take the transuranics. And the fission products, both noble and the ones that react to make the salt stay in that salt bath.

VICE CHAIRMAN CROFF: Okay. On your metal and ceramic waste forms, is it your belief they're going to be greater than 100 nanocuries per gram of transuranics, never be enough in those streams to make it to that level?

MR. LOEWEN: We need to look at that.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: So the separations work that's been done by the National Laboratories, and the research that we read in this conference, separation efficiency has variables, not a lot of variables, but has variables of the concentration of other constituents in the bath, the voltage you use, the time, and those sort of things.

VICE CHAIRMAN CROFF: Okay. On your Uranium product that comes out as a metal, how do you convert it to, I guess, either get to a hexaflouride or an oxide, or something?

MR. SAITO: Well, moving to oxide is going to be straightforward. You heat it in there, so you move it to E-308, then the E-308 will then either convert that back to ceramic for Can-Do fuel, or we will convert it, or sell it to a conversion facility to move it to UF-6.

VICE CHAIRMAN CROFF: Okay.

MR. SAITO: So it will be an E-308 -

VICE CHAIRMAN CROFF: Just to control burn, basically. Controlled oxidation.

MR. SAITO: Yes. A little bit of air, and as a dendrite, it should go over pretty rapidly.

VICE CHAIRMAN CROFF: Okay. The equivalent you have, if you want to get more throughput, how much larger can you make that equipment before you get into criticality problems, or some other kind of problem that would force you to have parallel lines.

MR. SAITO: Well, we are going to have parallel lines. I mean, that's clear. The criticality constraint, what we're looking at now is based on a safe mass of 400 kilograms per unit. And that way we can use moderation of mass, and have our two control variables as moderation of mass, and be able to run the units. So we'll size it at 400, and then run multiple units of off that type of size, which is 16 times larger than we sized a lot of our units for UO2, where the mass limit is 25 kilograms.

VICE CHAIRMAN CROFF: Okay. I was going to ask, the 400 is 400 kilograms of spent fuel charged to the -- in a batch or something like that.

MR. SAITO: In a unit. So if you have material coming in and coming out, your unit holdup is 400 kilograms.

VICE CHAIRMAN CROFF: Right. And how long does it take to process 400 kilograms of fuel? I mean, you put 400 into the thing, and you turn on the juice, and it does its thing. How long does it cook, if you will, before that batch is done, and then you have to recharge it?

MR. LOEWEN: On the order of 10 to 12 hours, depends on your current density, your surface area.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: So you're starting -- what we talked about was the demonstration in North Carolina, would be to build a unit with the criticality constraints that Dr. Saito was talking about for 50 metric tons per year.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: That's the scale that we would like to demonstrate at our facility in Wilmington, North Carolina. And then you would just replicate those lines.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: And to your specific question, you're probably sitting there for 12 to 18 hours in steady state, if you will, with the electro chemistry, very similar to what the aluminum industry does, that they're always adding electricity, they're putting the Bauxite in, and then when their aluminum level gets to a certain level, they just come in and pull out the aluminum. Do that every 12 to 15 hours on the different cells.

VICE CHAIRMAN CROFF: I noticed in your layouts, I guess it was the Burns and Roe design, you had two electro refiners running in parallel?

MR. SAITO: That's the Argonne one.

VICE CHAIRMAN CROFF: Oh, the Argonne one. Okay.

MR. SAITO: That's to go to 100 tons a year. It's a 50 ton unit.

VICE CHAIRMAN CROFF: Okay.

MR. SAITO: Fifty ton a year unit.

MR. LOEWEN: Yes, this is Argonne National Laboratories. So this is a report that they've done.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: They just provided these two slides to us, as far as to show what they're thinking about.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: We have not re-thought about it. We are still sitting with our 1995 report, and have gotten back into the business, because Global Nuclear Energy Partnership was announced in February.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: Argonne National Laboratory, through the AFCI program, is my understanding, looked at how to do 100 ton per year plant. And I think the same thing was being looked at for UREX, so I think you'd probably find a comparable report within the National Laboratories on UREX.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: Looking at this scale of a plant.

VICE CHAIRMAN CROFF: The Lithium Chloride that you're using, I'll call it a process chemical, or fluid, or whatever, I guess, can that be reused and recycled indefinitely, or does something build up in it where eventually you've got to get rid of it?

MR. LOEWEN: We expect that you're going to continue to reuse it, because you're cleaning it up. You're, obviously, going to have some losses of the Lithium Chloride, but we expect it is something you're going to be adding into your bath. For example, at EBR-II, they have not changed their bath, so they're continuing with the same Lithium Chloride, Potassium Chloride that they have in their electro refiner, and they continue to accumulate the fission products within there. And they've used that bath now I think since 1996.

VICE CHAIRMAN CROFF: Are they cleaning it up, doing the Zeolite thing out there?

MR. LOEWEN: They are not, because they have the flow sheet that's in your White Paper, where they're just -- once they get done, they will take that salt, add that glass frit and everything, and be done with it.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: So they're not looking at it as kind of a continuous, it's a waste cleanup of a fixed amount of spent fuel that they have on site.

VICE CHAIRMAN CROFF: Okay. They've got enough capacity in there to handle all the fission products they foresee, or something like that? Okay.

MR. LOEWEN: My understanding. I'm not expert on -

VICE CHAIRMAN CROFF: Okay. A little bit about volatile species. What happens to the Tritium and the Iodine that are in the spent fuel to start with? Do they come off as volatile species? Where do they come off?

MR. LOEWEN: The volatile gaseous species, which we'd expect Tritium would possibly be one of them, would be in that first step where you're disassembling the fuel bundle.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: It depends on how you're going to do that. We showed in the animation shearing, or you're chopping it up. We saw innovative technique in Korea last week where they run the rod and they split the cladding off. And there's also volatile oxidation where you're oxiding the O2 to E-308, and that causes the cladding to split. But either one of those three, the gases that are in the rods are going to be come out. What's unique about pyro processing, we're doing it in a hot cell and it's inerted. And so when you take those gases and you need to capture them cryogenically, and then do the separation, it makes it easier to do that if you're in an inert cell.

VICE CHAIRMAN CROFF: But the Iodine, in particular, I mean, you're dealing in Halite salts, if you will, Chlorides, obviously, but the Iodine doesn't react with all this other thing, get just lost in this mess of salt, does it?

MR. LOEWEN: No, we want it to be reactive and stay in the salt, is where we're -

VICE CHAIRMAN CROFF: Oh, so the Iodine is not volatilized, as far as you know.

MR. LOEWEN: We're expecting it to mainly reside in the bath.

VICE CHAIRMAN CROFF: Okay. And then the

Zeolite strips out the Iodine?

MR. LOEWEN: Yes.

VICE CHAIRMAN CROFF: Okay. It gets trapped along with Cesium, and all those other things.

MR. LOEWEN: And then that's what you're putting into your ceramic waste.

VICE CHAIRMAN CROFF: Okay. That's interesting. By the way, as an editorial thing, cladding stripping with fuel dug into the cladding could get a little bit ugly sometimes. So I'd ask a lot of questions before I jumped in that direction.

MR. SAITO: Well, we also have experience from bent rods in fuel facilities. And getting pellets out of tubing is not always the easiest thing to do.

VICE CHAIRMAN CROFF: Agreed. I think that's the point. I think maybe just a couple of sentences on background. Mike, in particular, asked a number of questions about waste classification. We've been asking this question, those kind of questions of a lot of people in a lot of different contexts, not just recycle, because the waste classification system has a lot of rough edges in this country, and we're seeing a lot of the ramifications of it. And this is just one more data point on a rather complicated graph.

Regarding the definition of high-level waste, at this point, it's a source-based definition. And I'm not going to quote all, either the official language in the law, and the translation of it in current NRC regulations, is basically they raffinate from the first cycle of solvent extraction, or what you could loosely translate as the first separation cycle. And none of those maps very well under your process. In other words, the definition was developed with a PUREX process in mind. I mean, let's face it. And have you probed the issue of whether you may need to have some changes, or at least some reinterpretation of that definition to figure out what is high-level waste or not?

For example, in a regular PUREX or UREX, either one flow sheet, the cladding would not normally be high-level waste. It's not low-level -- well, it's certainly greater than Class C, let's put it that way, or transuranic, whatever you want to call it, but it's not high-level, because you obtain it before you get to that first cycle of solvent extraction. I'm not sure what the case is, I mean, I'm not a lawyer. I'm not going to try, but have you asked any questions in those areas?

MR. SAITO: No. That's one of the things we're looking at as part of our current project. As you noted, the metal will come out, and it will be -- now it will be reintegrated with the fission products and other products from the spent nuclear fuel, so you can make an argument that it's very similar to first extraction from a raffinate. And that you've taken this, and you've reincorporated it back into that, because this is our extraction process, would be similar to the first extraction from raffinate. You've now taken this, and you've reconnected them together, so you could, from your definition, take it and say it is a high-level waste.

VICE CHAIRMAN CROFF: Doing that combination, you may be on -- well, if you call wanting high-level waste firm ground, but you may be on firm ground there, because even in PUREX, it's not all first cycle raffinate in tanks, or whatever. They use it as a place of convenience for other waste, just because it's the easy way to manage them.

Let's see, moving on. You mentioned in a couple of places in your view graphs the Morris facility. And I recognize sort of its history, and I guess it's still being used to store spent fuel, but I'm getting the impression from a couple of these that you have other plans for the Morris facility, at least possibly concerning pyro processing. I wasn't -- can you elaborate on what you've got in mind, or what you might do?

MR. SAITO: Well, it would be -- to stick with what the Department of Energy has asked for, we have two separate ideas. We have a process, which is pyro process fast reactor PRISM, and we have a site which is the Morris site. Now GE has put other restrictions on that, which is we will take our process onto our site, but we won't take other's processes onto our site, because as a landowner, we're using that prerogative. So we have blurred some of that together here, the idea being that you take your process, you build it, you build what we're calling a model home, which demonstrates the process. When you building a housing development, you build a model home so people can see what it looks like, and then they'll build their home behind it. The idea with Morris or another site is, we take these processes, we put them together, we build the model home. The utilities come and look at it, see if the economics is right, see if the technology is correct for them, and they'd buy off of that demonstration. So we are looking to build a full-size PRISM reactor, and a full-size pyro. process that is modular, so if a utility wanted to buy a 1.8 gigawatt plant, they'd buy six PRISM reactors and enough pyro processing units to meet that need. But they'd know the economics from the site that we put this at.

VICE CHAIRMAN CROFF: I see. Okay. And even though if at Morris, this would be a greenfield kind of a facility. I mean, you're not going to try to use any of the existing buildings and whatever up there.

MR. SAITO: We could, and that's one of the big advantages, when we talk to the Department, is that Morris provides built infrastructure. It has a license, it has suspended fuel already there, it has a pool, it has the beginnings of a processing building, whether that could be used correct for this new process or not is not there, it has discharge permits, because as we've discussed, you're going to have discharges from the site. They're going to need to meet Part 20 discharge limits, as well as state air quality discharge limits. Nothing is going to be zero, so you're going to have to have a measurable limit to go to, and a reason to go there. So Morris is a very good starting spot, because you don't have to do those first five steps. You have the spent nuclear fuel, at a NRC licensed facility that you can now start worrying about process on, not how do I get the material from the power plant to the process.

Now, in addition to that, right across the street is Dresden site, Exelon's Dresden site is right across the street. It has a few bundles of spent nuclear fuel in it, too. Down the road is LaSalle in one direction, and the other direction is Braewood, so there's no shortage of spent nuclear fuel in that vicinity to run these tests, and to do the demonstration from.

VICE CHAIRMAN CROFF: A little bit on the status of the Morris facility, and I don't mean the spent fuel storage, I mean, let me call it the old reprocessing plant, is there still equipment inside of it? Was it torn out, or just left, or what?

MR. SAITO: It is inoperable.

VICE CHAIRMAN CROFF: But it's still there?

MR. SAITO: Portions are still there.

VICE CHAIRMAN CROFF: Okay. And what is -- how contaminated did it get during testing? Was it -

MR. SAITO: It was only ever run with natural Uranium.

VICE CHAIRMAN CROFF: Natural Uranium, okay.

MR. SAITO: So it's all Class A waste. What's remaining is Class A waste in the facility. It's a matter of when do we discharge that material.

VICE CHAIRMAN CROFF: Okay. And does it have an -- are there NRC licenses associated with that?

MR. SAITO: Absolutely. It's the only off-site spent nuclear fuel storage facility in the country.

VICE CHAIRMAN CROFF: But that license also includes all those cells and whatever equipment is left?

MR. SAITO: Well, yes. As you know, things are complex. It's an agreement state.

VICE CHAIRMAN CROFF: Okay.

MR. SAITO: So to use natural Uranium, and that there's a little more complexity to it.

VICE CHAIRMAN CROFF: Okay. I hadn't realized that. I guess, are you, have you been, or are you in discussions with the NRC staff? I mean, like NMSS and FSME, about more or less everything we've talked about here, and where are you going?

MR. SAITO: Yes. And that's a great advantage of being a licensed fuel facility. We have both the Morris facility, which is licensed, we have the Wilmington facility, which is licensed, and we have the Vallacitas facility, which is a licensed facility. So we have great interactions with the staff, so we can discuss this with them. And we understand where people are looking at from a licensing space, so we have discussed with NMSS, we discussed this with Bob Pearson and his group, and had some productive discussions. But, of course, this is a big program. We're not going to go pursuing it off on our own at this time, so we're waiting to see where the program goes before we do any firm licensing actions.

VICE CHAIRMAN CROFF: Many are. I think with that, I've exhausted myself. John or Latif?

MR. FLACK: Okay. Just to follow-up a little bit on Allen's question. Right now, if the facility was to be submitted to the NRC, it would be licensed under Part 50 as a production facility, I assume.

MR. SAITO: We prefer Part 70.

MR. FLACK: Well, that's my question.

MR. SAITO: We think that's where the -- Part 50 is reactor licensing.

MR. FLACK: Right.

MR. SAITO: It's very good for reactor

licensing. Part 70 is really, we believe, the appropriate place for this type of facility. The Integrated Safety Analysis looks at the entire safety spectrum around the facility, and it's done very well for fuel facilities. It should do very well for this facility.

MR. FLACK: And ISA versus PRA, the kinds of accidents that could occur at the facility, I know we talked about criticality as being one. And, of course, there's no red oil-type accidents here. Are there accidents, and is it ISA adequate, or do you think a PRA might be more appropriate for looking at these kinds of accidents?

MR. SAITO: Well, the only difference between ISA and PRA is how stringent you use your calculation. The biggest difference is quantitative, when you quantify it, from my understanding. I'm very familiar with ISA. PRAs I'm less familiar with.

MR. FLACK: Okay. Well, then just about the accidents, the kind of accidents that can occur, other than criticality, are there any other kinds of accidents of significance where you would get source terms -

MR. SAITO: Well, as you mention, as you start collecting Iodine, Xenon, other radioactive materials in gaseous forms, we're going to have -- that's an off-site condition you're going to have to look at very carefully.

MR. FLACK: Where you could get an off-site release?

MR. SAITO: Where you could get an off-site release, so storage of those gases is going to be an important factor in an ISA. Dose rate, otherwise, site boundaries, you take the building away, is the general rule how you do an ISA on something like that. You take the building away and say off-site is there an issue? So direct dose rate, is there an issue? If there is, then you need to do an ISA, similar to what was discussed earlier today. That's why I agreed with the staff, I don't see where 11 kilometers away, where you have an issue of a spent fuel bundle coming down.

MR. FLACK: Okay. Although, you'd never really calculate the risk with an ISA. Of course, you use it as a tool to eliminate sequences that are significant, but you don't really calculate the risk with -

MR. SAITO: Yes, but you bound, you use a lot of bounding -

MR. FLACK: Well, that's where you could get into trouble, too, because really, when you do the ISA versus a PRA, there are certain things that are missing, like certain kinds of common cause failure, or common mode failures, which are not treated in ISA, which PRA captures, and other things, like human performance. The Committee is on record of writing a letter about the advantages of going to a PRA.

MR. SAITO: Well, I think ISA does take into account human performance. I mean, those are initiating events, those are causal factors.

MR. FLACK: Well, I would say as a cross-cutting issue in the plant, and how -- you're looking at sequence-by-sequence. Okay? So the importance of a human action across sequence is missed, because you're looking at a particular sequence to see if it meets a certain criteria, and if it does, you move on to the next sequence, and the next sequence, and the next sequence.

MR. SAITO: It is potentially missed, and I think that's some of the difference between ISA in theory, and ISA in practice, as we've put it in.

MR. FLACK: Okay. That's different.

MR. SAITO: When you start doing an ISA, you have to bound accident scenarios. You have to understand -- like I said, you say the building goes away. And then you start, and you figure out is that a problem. If the answer is yes, then you start sayin well, how can I get there? What are the accidents that can get me to that condition? So if you don't do those big thoughts and say this can cause me a big problem, so I need to bound all the conditions that can get me there, then you do run into what you're talking about.

MR. FLACK: Well, now you're moving towards a PRA kind of approach.

MR. SAITO: Yes. But you can't just sit in a vacuum and say I'm moving this cup from here to here. What can I do wrong?

MR. FLACK: No, I understand, in practice.

MR. SAITO: Yes.

MR. FLACK: You want to be smart about it, and that's why doing a PRA is really a smart way of doing. You doing an ISA to show each sequence is eliminated is not that smart way of doing things, and that's why there's always -- this issue comes up.

MR. SAITO: Yes. And that's where we get in many discussion with NMSS over, they say well, you didn't look at this exact sequence. We said no, we looked at the failure mode that this system failed, and what happened, and why did -

MR. FLACK: And ramifications.

MR. SAITO: Yes.

MR. FLACK: Okay.

MR. SAITO: So, yes, the system failed. Did we guess the exact sequence that caused that failure? No, but we made the system safe in the failure mode.

MR. FLACK: That's the bottom line.

MR. SAITO: Yes.

MR. FLACK: But it's these importance analysis, the sort of -- the effects across the broader set of sequences, which is important to calculate, that you do in a PRA, that you would normally not do in an ISA. But if you do it smart, you would be able to see these things, and fix them as you go along. And I agree with you, it comes down to the analyst.

MR. SAITO: Yes.

MR. FLACK: Which is true for a PRA, too. I mean, the analyst is always part of the equation.

MR. SAITO: And that's why it's very important, and that's why we think it's very important to go through a progression in the licensing step, because as a progression, when we learn together, and we get ourselves, the industry builds up a knowledge base. And it's not just a here it is, here's your facility, here's your building, is your ISA adequate?

Here's our building, here's our experience base, here's how we -- we've been inspected against this for some time. People have looked at our ISA, people -- the ISA has actually had to live through operations, not just be a theoretical exercise that occurred, and then we started running.

MR. FLACK: And it gives you expectations on how the plant should run with respect to performance, and reliability, and so on, to show that it comes true then.

MR. SAITO: Yes.

MR. FLACK: It's not just numbers pulled out of the air. Right?

MR. SAITO: Yes.

MR. FLACK: It's a very important tool. Another question on maintenance, and equipment outages, and aging of equipment. How long does this equipment last? I mean, is it maintenance-intensive, or does it just operate for years without requiring much activity there, or you still don't know? I mean, this whole issue -

MR. SAITO: Well, the anodes and the cathodes are somewhat maintenance-intensive. The actual units, themselves, should last a very long time. So the skeletons of the units will last a long time. Again, going back to when we went to Alcoa and visited the Alcoa facility, the actual scale of the units were 40, 50 years old.

MR. FLACK: Oh, is that right?

MR. SAITO: Now every year to two years, they rebuild the anodes and the cathodes.

MR. FLACK: So about every year or two years, and that requires a certain amount of down-time. How long is that down-time, for example?

MR. SAITO: It's going to be much longer in a hot cell.

MR. FLACK: Yes.

MR. LOEWEN: But, again, that's why we want -- the devil is in the details, and that's why we want to do that first component, electro reducer in Wilmington with the license with surrogates. And then we can come back with the quantitative information that yes, anodes last one month, and that's not going to work, or we have anodes that last a long time. In the aluminum industry, the tour that we took, their refractory lasts for five years. So, in that case, that component where they have a month shutdown to replace the refractory, it doesn't happen that frequently.

MR. FLACK: Yes. All right.

MR. LOEWEN: And that's where -- back to the fundamental mission of the National Laboratories, is we're buying technical options. But at some point, we should try to commercialize that technology as taxpayers, and so what we're saying is we want to commercialize that technology in a very methodical, bound the risk as we learn hand-in-hand with the Nuclear Regulatory Commission.

MR. FLACK: Okay. Just one more question. I see Andy Kadak back here, and I'm wondering, this thing, it's really tied to the liquid metal reactor. If you were to propose some other burner kind of reactor, how much do you lose? I mean, is it really not worth pursuing?

MR. SAITO: Well, is it a metal-based reactor?

MR. FLACK: Well, talking about fast gas cool -- well, a gas-cooled burner reactor with tri-cell fuel, for example.

MR. SAITO: You can always make the metal an oxide.

MR. FLACK: Yes. Right.

MR. SAITO: You can go from a E-308-type material that would -- it's no different.

MR. FLACK: Okay. So you're not losing

-- well, you'd have to go through that extra step, which means you're going to lose something in the process, I guess.

MR. SAITO: Yes. But you have a big advantage of not having aqueous system.

MR. FLACK: Absolutely.

MR. SAITO: You don't have the liquid waste, where we have our 50 acres of lagoons out in Wilmington that we had to go deal with.

MR. FLACK: Right. Right. I know those advantages. That's why I'm saying, it's not truly married to a liquid metal reactor. I mean, you could use this in other settings. It's just that GE has pursued the PRISM, and has tied this to the electro processing.

MR. SAITO: Well, the process has.

MR. FLACK: Yes. Right. Okay. Thank you.

VICE CHAIRMAN CROFF: I'd like to come back again, and extend one of my previous questions. On the volatile species, if you will, do you have any idea where the carbon is, and Carbon-14 goes? I mean, is it volatile, or stays in the salt, or something?

MR. LOEWEN: That one we haven't seen good enough documentation to give you a firm answer.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: So if I look at the literature, that radionuclide I still have concerns that we need to figure out where it goes.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: And so that's the sort of stuff that we can do with surrogates in Wilmington.

VICE CHAIRMAN CROFF: And the complementary question, on the volatiles, I've been asking you about the usual suspects, if you will. But given that you're at fairly substantial temperatures, several hundred C, is there anything else, any other fission products or activation products that are volatile at those temperatures, that we aren't familiar with, that we haven't seen before?

MR. LOEWEN: What they've done in EBR-II, when you look at their cell, you're not seeing those species being volatilized, so they're forming chloride salts, and they're staying within the -

VICE CHAIRMAN CROFF: Okay. The vapor pressures of all those salts are quite low at those temperatures?

MR. LOEWEN: Yes.

VICE CHAIRMAN CROFF: Okay.

MR. LOEWEN: Now when you go to the fuel fabrication, if you start looking at the literature, when they were cast in actinide fuels, then you had the issue with the Americium volatilization.

VICE CHAIRMAN CROFF: Yes.

MR. LOEWEN: And if you look at what's being done in the advanced fuel cycle initiative, by looking at how to cast faster so they're not at temperature longer, so they minimize that volatilization of the Americium.

VICE CHAIRMAN CROFF: Okay. I'm sorry. Latif, do you have a question?

MR. HAMDAN: I do, on this, Mike.

CHAIRMAN RYAN: You know, in that actinide step, too, I think there's one additional thought that strikes me, and that's the radiation protection requirements for workers is up a big notch. You're dealing with alpha emitters, typically, any intake is a problem, number one, because you have to assess it, and you're typically assessing over very long periods of time on the individuals exposed. And then, two, all the protection requirements are at the top of the scale in terms of protective clothing, respiratory protection, all that activity. Have you thought about that aspect of actinide work?

MR. SAITO: It's going to be in a hot cell, so I'm a little confused.

CHAIRMAN RYAN: Well, that's all well and good, but things go in and out of hot cells. People have to deal with that. You don't close up a hot cell, and close it forever. Stuff goes in, stuff has to come out, doesn't it? I mean, there are worker -

MR. SAITO: I don't see -- I mean, there will be decontaminate -- I don't see much higher than the Uranium facilities we run.

CHAIRMAN RYAN: Oh, Uranium and Plutonium are night and day.

MR. SAITO: Yes. I mean, as specific activities go -

CHAIRMAN RYAN: No, in terms of radiation protection requirements.

MR. SAITO: Yes, well, that's driven by specific activity.

CHAIRMAN RYAN: Not exactly.

MR. SAITO: Well, yes, because you're worried about nanograms, instead of grams.

CHAIRMAN RYAN: Atom-for-atom, Plutonium gives you much different dose profile than Uranium. In fact, Uranium oxide is chemically limited, not radiologically limited.

MR. SAITO: Well, it's driven by the specific activity, because you get more alphas off of a gram of Uranium.

CHAIRMAN RYAN: Okay.

MR. SAITO: It's something that I haven't considered, but I think that -- we'll give that more thought.

CHAIRMAN RYAN: Okay. Thanks.

VICE CHAIRMAN CROFF: Latif?

MR. HAMDAN: Yes. I want to go back to the waste types and waste form. Can you tell me the reasons why you process does not include creating waste streams that would have a home? I mean, is it technological reason that your waste streams, you end up with waste streams that don't have a home, and you create a problem for yourself that you need to resolve? Isn't there a way you can either change your process, or add something to it, with the waste streams in mind, so that you end up with waste streams that actually do have a home?

MR. LOEWEN: Yucca Mountain has -- its current Waste Acceptance Criteria is it takes spent nuclear fuel, in wrapped several layers of engineered barriers around it to protect future civilization. Okay? So it has a home, by a legislative process we have defined that waste package.

This process is putting those fission

products into forms that they like, either ceramic or metallic waste form. And to my mind, that's -- fundamentally, you've got a waste form that's going to be a lot more rugged in the repository than other options. And, so, we have to decide whether on a probabilistic or a risk-assessment sort of view, what the leachability is of those two different waste forms, and is this a better path to go down?

MR. HAMDAN: So you do believe, because I understood in your answer earlier, that you may have some waste streams that do not have a home, but you are saying that you believe that there will -- you think this waste will have a home in Yucca Mountain, or elsewhere. Right?

MR. SAITO: Yes. Our general process waste streams will have a home. What Michael talked about was, what about the upset processes, and could that cause things that are an issue? And we agree that that's something that needs to be studied further.

CHAIRMAN RYAN: Yes, I would add, too, I don't agree that all your wastes have a home, because you could argue that your ceramic wastes are not high-level waste by the definition that's authorized for Yucca Mountain. It could be a legal argument against what was envisioned for Yucca Mountain. I'm sure that would be challenged. If you just accept the fact it's acceptable under the Waste Acceptance Criteria for Yucca Mountain, I think that's a reach.

MR. LOEWEN: That you could put the ceramic waste in Yucca Mountain?

CHAIRMAN RYAN: Yes. I'm not saying it's not similar, and has the same kind of characteristics, but I think it's a reach to say it's acceptable at this point in time. That hasn't been -- nobody said that's right.

MR. SAITO: It would be somewhat ironic if you make it not radioactive not to only Yucca Mountain, if that's our issue.

CHAIRMAN RYAN: Absolutely.

MR. LOEWEN: But Yucca Mountain, also, is supposed to take the glass logs from Hanford. Obviously, those have actinides and some other constituents, but it -

CHAIRMAN RYAN: Well, what's acceptable to Yucca Mountain, is specifically listed. Your's isn't.

MR. LOEWEN: That's correct.

CHAIRMAN RYAN: That's my point.

MR. LOEWEN: That's correct. We agree.

MR. HAMDAN: That's it.

VICE CHAIRMAN CROFF: Okay.

MR. HAMDAN: There's somebody in the audience.

VICE CHAIRMAN CROFF: No. Dan, you had a question?

MR. TAYLOR: Yes.

VICE CHAIRMAN CROFF: Your name, and organization, please.

MR. TAYLOR: Dan Taylor, NRC. Can you tell me materials of construction? How are you going to make, what are you going to make this stuff out of?

MR. SAITO: The units?

MR. TAYLOR: Right. Do you have corrosion problems? I mean, just the equipment itself.

MR. LOEWEN: How about -- we have a good picture. Let's look at the electro reducer.

MR. TAYLOR: Okay.

MR. LOEWEN: So the electro reducer uses a stainless steel bucket, if you will, that holds the molten salt. It's resistably or inductively heated. I've seen both designs in my travels to Korea, Japan, and Argonne National Laboratory. And then you have a stainless steel closure on top. Those salts are compatible with stainless steel.

MR. TAYLOR: Okay. Now that's if everything is dry. Right? But don't you have Tritium in the spent fuel, and don't you have oxygen? And do you form water in this system? And, if so, where does the water go?

MR. LOEWEN: The first step, this electro reduction, you've taken that oxide fuel, and you're putting it in the bath at 600 degrees C, and so at that point, if you do have the Tritium or water, you have volatilized that, and collected that in your off-gas system. So now when you have this reduced metal, you take that basket, and you put it directly into this basket, the electro refiner.

MR. TAYLOR: So the water problem would just be in the initial step.

MR. LOEWEN: Correct.

MR. TAYLOR: Okay. How much Lithium Chloride waste do you generate per metric ton of heavy metal? Do you have any numbers on that?

MR. LOEWEN: No, I don't have specific numbers.

MR. TAYLOR: Okay. Because it seems like you would have some interfacial rag that would build up in there, just like with -- it seems to me the chemistry here is somewhat similar, what they had at Rocky Flats in terms of Plutonium foundry. And I would expect to get some kind of foundry-type waste, which they had a mix of salts, and they had then Plutonium metal mixed in with the salts, because it would condense out and form little droplets. It's actually pyrophoric, so do you think you need the waste to be pyrophoric, and have problems with Plutonium metal contamination?

MR. LOEWEN: No. The metallic waste form, you're mixing Iron and Copper, and you've taken out your pyrophoric metals of Uranium and Plutonium, and you've taken those out. So that waste form is not pyrophoric.

MR. TAYLOR: Well, I was wondering if you'd have to calsign any of the waste to meet the 30.13 standards, and have a stabilized waste before you can actually dispose of it.

MR. SAITO: What you're saying is, would there potentially be trace metals in there that you'd have to do.

MR. TAYLOR: Yes. Right.

MR. SAITO: And we would have to look at that. My initial thought would be no, because it would oxidize. It would be fine particulate that would oxidize rapidly to start with, so it wouldn't be pyrophoric after it's been through any kind of treatment.

MR. TAYLOR: Okay. Do you have any numbers about how much Plutonium is in the salt waste that you generate from this process?

MR. LOEWEN: Again, that's one that -- in the literature, it depends on the variables of how the process is run, as far as what separation -

MR. TAYLOR: Okay.

MR. SAITO: It's in the parts per million range, though.

MR. TAYLOR: So the complementary question is, what kind of recoveries do you get for the actinides, particularly, the minor actinides?

MR. LOEWEN: For the actinides or the minor actinides?

MR. TAYLOR: Yes. Well, say for Plutonium and Neptunium, can you give me numbers on recoveries?

MR. LOEWEN: The decontamination factor that's on the order of 9,000 to 10,000, as far as your separations.

MR. TAYLOR: Well, what about actual recoveries? There's a recovery of the Plutonium that was originally in the spent fuel. What percentage of what's in the spent fuel is actually recovered, and ends up in another fuel form, as opposed to being in the waste?

MR. LOEWEN: That's one of the parameters we have to measure. I do not have an exact number.

MR. TAYLOR: Okay.

MR. LOEWEN: Because we're trying to commercialize the technology from National Laboratory. They've done the research.

MR. TAYLOR: Right.

MR. LOEWEN: And in that commercialization process, we need to learn, and we need to come and work with the regulator to give you those exact numbers. Just like when we took the data from VORAX-3 from Idaho or the National Reactor Test Station in the early 50s from Idaho National Laboratory, we commercialized boiling water reactors. They've gone a long way since VORAX-3.

MR. TAYLOR: Right.

MR. LOEWEN: And we've gone hand-in-hand with the regulator in learning as we slowly increment to make that process better. So the Department of Energy has asked GE to take a look at doing a solution to the Global Nuclear Energy Partnership. We have given a system that we think is economic, it's safe, and it's viable. And those specific questions we realize we have to answer, not only for you, but for our internal risk, the way we look at a process. Do we want to put our name on it?

MR. TAYLOR: Okay. Let me ask you about aerosols. Do you have any aerosol numbers, what kinds of salt aerosols you get with this process during normal operations, and things like that?

MR. LOEWEN: Typically, the container you're seeing here, the aerosols, you don't have that issue, because you're using it in covered containers. And it's just when you start transferring a basket from the electro reducer to the electro refiner, that's when you have the issue of the aerosol.

MR. TAYLOR: Okay.

MR. LOEWEN: Again, you're in a hot cell. You have the HEPA filters, you're taking that stuff out.

MR. TAYLOR: So what does it do to the HEPA filters?

MR. LOEWEN: It would play out on the HEPA filters, would cause a higher differential pressure.

MR. TAYLOR: Okay. Great. Thank you.

MR. LOEWEN: Thank you.

MR. KADAK: This is Andy Kadak, again, from the Waste Board, but interesting questions about the GNEP and the volume reduction. I was surprised that it's only a 50 percent volume reduction, because as I read the literature about GNEP, we only need one repository forever. Now are you meeting those goals in your pyro processing?

MR. LOEWEN: GNEP is -- okay, to answer your specific question, Professor Kadak, the Global Nuclear Energy Partnership, as it's been defined since February of 2006 to now, has evolved, and it's in the eyes of the beholder. Okay?

MR. KADAK: Okay.

MR. LOEWEN: On what the goals, and what GNEP should be. The numbers that I'm telling you is from an engineering design work that we in the Advanced Liquid Metal Reactor program came up with four different plans, use the best information they could get from the National Labs at the time. And when I look at their numbers, I see about a 50 percent waste reduction.

MR. KADAK: Okay.

MR. LOEWEN: Okay? Now should that be improved? It could be, and it depends on what sort of waste loading you can do. Now they were trying to put this stuff in Yucca Mountain, or a repository, and so they perceived the limit was 1 kilowatt per meter. And they were trying to make a waste package to meet that limit. Now if you decide not to, and put it above ground, and let it sit there and decay, then your waste loading goes up considerably, and your volume of waste will go down. So the constraints, when I gave you those numbers, were based on the idea that there were not orphans, that all children were loved, and that these two waste forms, metallic and ceramic, were going to go to a repository.

MR. KADAK: Okay. Now do you have any more detail about what the waste forms actually are at this point, even analytically, in terms of constituents, and the form of the waste itself?

MR. LOEWEN: Yes. The metallic waste form is an alloy of Iron, Copper, Zirconium, and the noble fission product metals.

MR. KADAK: So you would that in that report, as well? Because we heard a presentation at the Waste Board meeting, and there was a lot of movement about what, in fact, is going to be the waste form coming out of GNEP. And, obviously, from the Waste Board, we'd like to know what those are, and how those can be better or worse than what we're now putting into the repository, or planning to put into the repository?

MR. LOEWEN: Well, that's pretty defined, the metallic waste form, the ceramic waste form.

There's a lot of different ceramic systems you can go into. So we saw last week in Korea, they're using calcia silica phosphate, because they feel that Zeolites can't handle the temperature. If you look at a lot of work that's done at Savannah River National Laboratory, they're using a borosilicate glass. Also, calcia silica.

MR. KADAK: And is this going to be a big research program to define the waste form so that it is suitable for disposal, or do you think that's more or less a done deal?

MR. LOEWEN: I think you start with the waste form that's been approved with an EPA environmental impact statement, that was used for the disposal of EBR-II fuel. So they have -- and that's where we would start, from a known starting point, and see if that is adequate to meet the Waste Acceptance Criteria.

MR. KADAK: Okay. The last question, I would like to follow-up on John's question about the accident scenarios. Could you just be a little more specific about what kind of accidents that you have to worry about in terms of a reprocessing facility, such as this, in terms of what are the risk drivers? You mentioned something about Xenon, and I think Krypton

I think you mentioned, but what would be the dominant risk accident sequence, if you will?

MR. LOEWEN: After criticality?

MR. KADAK: Yes.

MR. LOEWEN: Okay. So that's the dominant one, that is the most concern. And then when you look across this facility, if you look at the dry storage facility, where you're bringing in spent fuel from the fast reactor, it does have some sodium on it. You are using air-cooling, so you could get yourself into scenarios of what-ifs, they get knocked over, if you don't have a separation, if you don't have the cooling, so you have those issues with that part of the plant. If you look at the spent fuel pool, it's many of the same issues the Commission is wrestling with with spent fuel pools at our current nuclear power plants.

Along with the process, you have that cell, and you're doing the process that we talked about, and you have a defined amount of source term, so you define how much you want to have in process. And this particular process some say is limited because it's batch. In this case, you know exactly how much is in there, and you can decide what your source term is on those different scenarios. So now you have what happens in process upsets, what happens if you lose electricity, what happens if you lose an anode, what happens if a crucible breaks? And so those are the sort of -

MR. KADAK: And that's all in the hot cell, if you will?

MR. LOEWEN: Yes, that would be in that center part of the plant, would be in that hot cell.

MR. KADAK: So there's no radioactive stream coming out of the hot cell, more or less. It would be solid? Sorry?

CHAIRMAN RYAN: That would be the idea, I guess. But there's no guarantee. I mean, you could go through the design process and figure that out.

MR. KADAK: Okay. Thank you.

MR. LOEWEN: Okay. Thanks.

MR. KADAK: Allen, you have someone at the microphone.

VICE CHAIRMAN CROFF: Sorry.

CHAIRMAN RYAN: Nick Apted is back there.

MR. APTED: Nick Apted with Monitor Scientific. As one of the members on that National Academy panel, I was sort of interested in how you captured sort of the overall flow of that. I don't know if we can go to that flow diagram from that report, because I think it's interesting to me to see how the situation has sort of evolved, I guess, from there, the types of waste forms that were considered, to the ones in your later flow diagram. I think some of these issues that ACNW are raising in some ways are addressed here, because of the change.

The key thing you say, though, that the technical, sort of technical process was affirmed, but that report also raised a number of points. I think you're addressing, and one was sort of the industrial throughput in terms of the reliability, and some of the questions, accidents and so on, seems you're well on that. The other part, also, was the waste forms. And, again, I think the ACNW has been doing a good job on sort of identifying concerns about that.

Just to take up some of the points in terms of maybe some of the answers, certainly, the Carbon-14 appeared at that time to be in graphite, and the graphite, again, where it was going, whether it was going to go into the metal waste form, or whether it was going to be into the Zeolite was still an open question. But the chemical form was not as a volatile, but as a very react - what's the word I'm looking for - very high-temperature solid.

The Iodine-129 was going into the Zeolite, along with the Chlorine. It's important to remember that the Zeolite cage for charge balance is being filled up not only with the anines, the Cesium, and Strontium, but also with the charge balance chlorine, so a lot of the chlorine is disappearing, as well as the Iodine into the Zeolite.

The one problem that was not addressed at the time was Chlorine-36. Now some origin calculations show a considerable amount, or a reasonable amount of Chlorine-36 in fuel, and that probably will build up in the salt reactor, itself, so it's something to think about.

My question was, on the recycle, at the time, there was a worry about Uranium-236 building up after several recycles. Is that still an issue for this?

MR. SAITO: If you had a light water fuel?

MR. APTED: Yes, that's right.

MR. SAITO: Yes. That would be an issue, because -- well, that would be an issue with centrifuge or diffusion technology.

MR. APTED: Sure.

MR. SAITO: If you go to laser separation, it's not an issue.

MR. APTED: Right. So, eventually, you would envision some Uranium bounds might be unsuitable, or have to be blended or something to make it into a suitable -

MR. SAITO: Yes. You'd have to -- we figured on the first pass-through, you lose about 4 percent reactivity.

MR. APTED: The last two points, again, everybody -- speaking last, everybody takes all your good points. Andy mentioned the presentation on GNEP to the Board earlier this spring, and Jim Lay there gave a very good talk about the waste forms they saw coming out of pyro processing, which were different than either shown here or on your later diagram. And he labeled those intermediate-level waste forms, and I think that's partly the influence of AREVA coming in, because that's IAEA terminology, intermediate-level waste forms. But those intermediate-level waste forms are probably the most difficult types of waste forms to isolate. The Swedes, the Finns, the Japanese, everybody is having a hard time finding a suitable geologic disposal, which is IAEA recommends, is geologic disposal, so it is worth digging into in terms of solving one problem of spent fuel, and creating these kind of waste forms that could be more difficult.

And, lastly, it fits into, I think the panel, the last part we go into was the Waste Acceptance Criteria for Yucca Mountain. And we looked at these waste forms, of whether they would be acceptable or not. And at the time, Argonne was doing these product consistency tests, which at that time was all that Yucca Mountain was requiring. Now, maybe they've gone passed that, but given that they have the right parentage to go into Yucca Mountain, Yucca Mountain wasn't so worried about the form, as long as they would meet these product consistency tests. So I think there's an avenue forward in terms of the type of waste forms you might generate. But I am a big fan of the Korean waste forms. I think that those apatite waste forms are far superior to what's being looked at in the states.

MR. LOEWEN: Thanks for the comments.

MEMBER CLARKE: If I could just follow-up on this whole issue of volume reduction. It seems when you ask that question, you have to say volume reduction with what? And I think that's where you were going with your answer. But I recall reading some of the literature from Argonne, statements that the actinides could be reduced by as much as 95 percent. Is that consistent with your understanding?

In other words, they frame the question under what is the volume reduction of constituents that would require long-term isolation and with the actinides? And I think they came up with very high 90s for using it as a fuel in fast reactors. Is that your understanding?

MR. LOEWEN: Sure. And then that's consistent with the number that I gave, because you're taking those actinides and putting them in a fast reactor. So you've taken 95 percent of them away.

MEMBER CLARKE: So if you separate out the fission products as maybe stuff that doesn't require long-term isolation, then you're left with growing reduction numbers like that, I guess.

MR. LOEWEN: Correct. But I'm basing it off of how the Advanced Liquid Metal Reactor program was approaching the problem of how to get rid of the spent fuel.

MR. FLACK: Can I just follow-up, just to make it clear, getting back to Andy Kadak's question, that going forward with this process, you would only need one Yucca Mountain. Is that right? Because you would be burning up the actinides, and then if you let the fuel sit before you put it into the mountain, because you're not separating out the Cesium and

Strontium that's going to be there, that you'd have to let that sit before you put it. And since it's the heat load that's driving the amount you can put into the mountain, if you did it right, you would only need one Yucca Mountain. Is that what you're saying, or you think there's going to be limits to this, to where you're going to need another additional repository?

MR. SAITO: I think we need to get one Yucca Mountain running, and accepting waste, and then we can talk about the final numbers that we'll end up with. Yes, in principle, yes, we could do it that way. But we need to have firm rules, and clear path forward, and a way to put it in. But, fundamentally, you've taken 95 percent of the fuel and Uranium and removing it from the system, so right off the bat, you've taken away almost all the weight, and 80 percent of the volume. So if you look at it from that perspective, you would think, intuitively, you could make it work.

VICE CHAIRMAN CROFF: Okay.

MR. REID: I'm Phil Reid from the NRC. I just have two quick questions. The first deals with separation of Strontium and Cesium. In the aqueous reprocessing that can easily be done in order to do further heat load analysis from Yucca Mountain. And I was curious, in your process, do you allow for the separation of Cesium and Strontium?

MR. LOEWEN: The first electro reduction in the Lithium Chloride bath, the Cesium and Strontium will form salts and stay there, is what we're seeing in the literature. In that case, if you wanted to just purify that salt stream by itself, you could get Cesium and Strontium.

Now when you go to the electro refiner, the next process block over, now you're getting the rest of those fission products in there. If you blend those two, now you have all the fission products that stay in the glass, Iodines and the other ones, or you could keep them separate. So that's -- I know the last Committee meeting you had in July, the debate came up, should you separate Cesium and Strontium, what's the advantage of that? And so in this process, if you want to, you can, because in that first electro reduction, you do get that, just because of the chemistry. And it depends on how you treat your two salt baths, whether you keep them separated or not.

MR. REID: The other question I have is in the separation of the transuranics. I understand Argonne is thinking now of using a Cadmium electrode process, and I'm not sure how much information is available on that, but I was curious in using that process, do you get full separation, say of the curiums and the other Neptuniums like that, or are you just principally interested in separating the Plutonium?

MR. LOEWEN: We're doing a group separation of all the actinides, and that's because the electro chemistries is similar. And so the only one that's off to where you can pull out separately is the Uranium, so we have to take them all. We can't just extract Plutonium. And that's why this process, from a proliferation standpoint, lends itself, and why it probably migrated to Japan and Korea, with very little -- I'll leave it at that.

MR. REID: I was mainly curious about the separation of the Americium, and maybe the Curium. I understand it works fairly well with Plutonium and Neptunium, but I was curious, do you have any experience with using that, or are you relying mostly on the results from Argonne at this stage?

MR. LOEWEN: We, General Electric, have no experience, because we have not run this process. And, so, again, we are doing -- if the government asks us to close the fuel cycle, we presented an integrated solution, and we will work with the government to commercialize this technology, if that's what we want to do as a nation. And we need to also be able to start generating this, so our first step has been, okay, let's put an electro reducer on our site, and put it at a scale of 50 metric tons per year, and start generating that data so that we could come back to you and say here's what we know about it, because we're looking at this technology that's coming from a National Lab.

MR. SAITO: But to Eric's point, Eric brought this chart up here, you can see the Plutonium and Americium are very close in electric potential, so they will come together. So, yes, the Americium and Plutonium will come together, Neptunium is a little further off, so if anything that wouldn't come along, would be the Neptunium. I think the issue you're talking about, also, is the Americium in the cast fuel had some volatilization issues. So that wasn't in the separations here, that was in the casting part.

VICE CHAIRMAN CROFF: I think with that, we've reached the appointed hour. I'd like to thank you -

MR. SMIRY: Could I just ask one quick question, if I could, please?

VICE CHAIRMAN CROFF: Very quick.

MR. SMIRY: It will be very, very quick.

Alex Smiry. I'm with NMSS. I just have a very quick question about the heat load reduction. I recall in one of your slides, you show the different heat curves from the different isotopes, and if you were to run this process, and it ran the way it was intended, do you have any feel for what the heat load reduction would be, because, ultimately, the heat load of the fuel determines the size of the repository.

MR. LOEWEN: Yes. This is a slide that we got from your White Paper on reprocessing, and so we believe that the pyro process will follow this curve here of the fission products. So the waste forms we have are going to follow this heat curve. That's what we're going to get out, that was long-term constituents of the actinides. And that's where we see the environmental benefit of this. We see heat load as really the driver to future generations, or how you make a repository.

VICE CHAIRMAN CROFF: Okay. With that, we've reached more than the appointed hour.

MR. LOEWEN: Thanks for having us.

VICE CHAIRMAN CROFF: Thank you very much for the presentation, and your patience with the questions. I think the presentation really hit the mark in getting us, at least, a little bit smart on something where we had relatively little understanding, I think it's fair to say. And with that, I'll turn it back to you, I think, Mike.

CHAIRMAN RYAN: Thanks. And with that, we will close the record for the day, and thank all for participating on a full productive day. Thank you all very much. We will reconvene at 8:00.

(Whereupon, the proceedings went off the record at 5:05:30 p.m.)

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 183rd 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.

DEVELOPMENT OF NRC'S SEISMIC REGULATIONS: A PRELIMINARY OVERVIEW

Michael P. Lee
Advisory Committee on Nuclear Waste & Materials Staff
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301/416-6887

October 16, 2007

1

Questions ...

- What does NRC require of its licensees in the area of seismic design?
- How did the staff arrive at its decision-making?
- How do the seismic design requirements in 10 CFR Part 63 compare with other NRC regulatory regimes?

2

Answers ... looked at the literature

- Examined public sources of information
  - 250+ citations
- Including but not limited to ...
  - NRC Regulations
  - Statement of Considerations (*Federal Register* Notices)
  - Review Plans
  - Regulatory Guides
  - Staff Positions
  - SECY Papers
  - Technical Assistance Reports
  - Scientific Journals

3

Answers ...

- NRC's seismic criteria vary ...
  - Type of fuel cycle facility
  - Prevailing regulatory framework in place at time of licensing
- Reasons ...
  - Evolution in earthquake engineering science and technology
  - Radiological hazard posed by facility operation

4

Answers ....
Seismic Events of Regulatory Interest

DRAFT

Facility Type		Regulation - 10 CFR	Seismic Event of Regulatory Interest
Nuclear Power Plants	(before 1997)	Parts 50 and 100(Appendix A)	maximum historic earthquake
	(after 1997)	Parts 50, 52, and 100	maximum historic earthquake
Geologic Repository for High-Level Radioactive Waste (surface facilities)	(generic)	Part 60	potentially adverse condition
	(site-specific)	Part 63	features, events, and processes
Independent Spent Fuel Storage Installations		Part 72	geological/seismological characteristics
Low-Level Radioactive Waste Disposal Facilities		Part 61	unfavorable site features
Mixed Oxide Fuel Fabrication Facilities		Part 70	natural phenomena & external events
Other Fuel Cycle Facilities		Part 70	natural phenomena & external events

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Answers ...
Seismic Design Criteria - DRAFT

Facility Type	Seismic Criteria	
	Design Earthquake	Minimum Ground Acceleration
NPP	10^{-4}/yr SSE	0.1g
	10^{-5}/yr SSE (median) 10^{-4} /yr SSE (mean)	0.1g
HLW Repository (preclosure surface facilities)	one or more times during facility lifetime- 10^{-2}/yr event (Category 1 DBE) unlikely but credible event during facility lifetime - 10^{-4}/yr event (Category 2 DBE)	0.1g
	once during facility lifetime - Category 1 ES[10^{-3}/yr] one chance in 10^{4} during facility lifetime -Category 2 ES [10^{-4} /yr]	none
LLW Disposal Facility	10^{-4}/yr event	none
MOX Fabrication Facility	5 x 10^{-4} /yr event	0.2g (west) 0.25g (east)
ISFSI	5 x 10^{-4} /yr event	0.1g
	≥ SSE for NPP	
Other Fuel Cycle Facilities	licensee-proposed [10^{-3} - 10^{-4}/yr event]	none

6

Next Steps ...

- Complete and document literature review
  - Issue as a background paper
  - Focus on facts and history
  - Provide NRC staff with knowledge management tool
- Report has no legal/regulatory standing
- Time table
  - Coordinate internal review (NMSS, RES, NRR, NRO)
  - Issue public draft in November-December time frame
  - Seek focused external peer review
  - Finalize as NUREG

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ACNW&M Background Paper: Table of Contents - DRAFT

APPENDICES

8

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

183rd ACNW&M Meeting
Working Group
Pre-closure Seismic Analysis Evaluation at the Proposed Yucca Mountain Repository
October 16, 2007

Current Seismic Design Requirements for Nuclear Power Plants

Goutam Bagchi
Office of New Reactors
U.S. Nuclear Regulatory Commission

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Outline

- Seismic Design Requirements (New Plants)
- Seismic Load or Demand
- Reference Probability Based Demand
- Performance Based Demand
- Structural and Mechanical Design
- NUREG 0800: Standard Review Plan
- Seismic Margins Criteria
- Seismic Core Damage Estimate

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Regulatory Framework

- 10 CFR Part 100.23 Geologic and seismic siting criteria
- 10 CFR Part 52 Subpart B: Standard Design Certification
  - High level of generic design response spectrum
- 10 CFR Appendix S to Part 50--Earthquake Engineering Criteria for Nuclear Power Plants
  - Includes a minimum seismic load consideration

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Seismic Load

- Seismic load or demand
  - Probabilistic seismic hazard analysis
  - Site response analysis
  - Site-specific ground motion response spectra
    - Reference probability based – median annual frequency of exceeding earthquake load is 10^{-5}
    - Performance based – mean annual frequency of exceeding earthquake load is 10^{-4}

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Seismic Load

- Reference probability based seismic load
  - Regulatory Guide 1.165, "Identification and Characterization of Seismic Sources and Determination of Safe Shutdown Earthquake Ground Motion" – applicable for new plants after 1/10/1997
  - The reference probability is the annual probability level such that 50% of a set of currently operating plants has an annual median probability of exceeding the SSE that is below this level
  - The reference probability value is 10^{-5}

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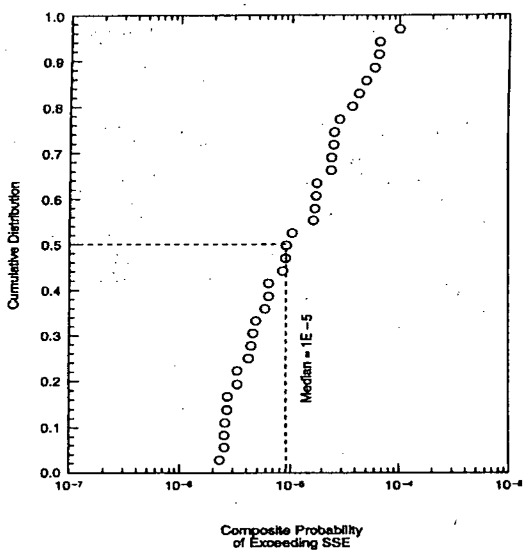

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Seismic Load

- Performance based seismic load
  - Regulatory Guide 1.208, "A Performance-Based Approach to Define the Site-Specific Earthquake Ground Motion" – applicable for use with 10 CFR Part 100.23 (plants after 1/10/1997)
  - Performance-based ground motion from ASCE Standard, 43-05, "Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities"
  - The seismic demand and structural capacity evaluation criteria laid out by the NRC's Standard Review Plan (NUREG-0800) ensure sufficient conservatism to reasonably achieve both of the following:
  - (1) less than about a 1% probability of unacceptable performance for the site-specific response spectrum ground motion
  - (2) less than about a 10% probability of unacceptable performance for a ground motion equal to 150% of the site-specific response spectrum ground motion

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Structural Design

- Structural and mechanical design - deterministic
  - Analysis models – redundant load paths
  - Damping values
  - Earthquake time histories enveloping response spectra
  - Concurrent loads from accident conditions – pressures, temperatures etc
  - Actual sizes frequently greater than those required by allowable acceptance criteria
  - Conservative acceptance criteria
  - Overall response essentially elastic

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Seismic Design Guidance

- NUREG 0800: Standard Review Plan
  - Guidance on all aspects of loads, load combinations
    - Interim staff guidance on consideration of realistic effects of ground motion – incoherency, high frequency contents
  - Modeling of structures and components
  - Limits on damping
  - Conservative acceptance criteria based on industry codes and standards – exceptions from code provisions, when deemed unjustified for nuclear power plant designs

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Seismic Margins

- Seismic Margins Criteria
  - All new and advanced reactor are expected to withstand earthquake loads beyond the design basis loads
  - PRA insights will be used to support a margins-type assessment of seismic events. A PRA-based seismic margins analysis will consider sequence-level High Confidence, Low Probability of Failures (HCLPFs) and fragilities for all sequences leading to core damage or containment failures up to approximately one and two thirds the ground motion acceleration of the Design Basis SSE.

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New Reactor Seismic Performance

- Seismic core damage estimate
  - With performance based seismic design using RG 1.208 and a seismic margin of 1.67, mean seismic core damage frequencies are estimated to be between $5x10^{-6}$ and $1x10^{-6}$ per year
  - Seismic core damage frequency for new plants with standard seismic designs should be even lower

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Preclosure Seismic Design and Performance Requirements for the Yucca Mountain High-Level Waste Repository

Mysore Nataraja

Briefing to Advisory Committee on Nuclear Waste and Materials

October 16, 2007

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Outline

- Purpose
- Regulatory Framework
- Seismic Hazard Assessment
- Design Methodology
- Proposed DOE Approach
- Staff Feedback to DOE
- Current Status
- Summary

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Purpose

- Describe 10 CFR Part 63 regulatory framework for the preclosure seismic design/performance requirements
- Provide historical perspective on the YM preclosure seismic design methodology
- Describe current YM preclosure seismic design methodology

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Regulatory Framework

- 10 CFR 63.112 Requirements for preclosure safety analysis of the Geologic Repository Operations Area (GROA)
- 10 CFR 63.111(a), 111(b)(1): Category 1 Event Sequences are those that are expected to occur one or more times before permanent closure of the GROA
- 10 CFR 63.111(b)(2): Category 2 Event Sequences are those other event sequences that have at least one chance in 10,000 of occurring before permanent closure of the GROA
- No prescriptive seismic design requirements

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Seismic Hazard Assessment

- DOE Topical Report YMP/TR-002NP, Methodology to Assess Fault Displacement and Vibratory Ground Motion Hazards at Yucca Mountain (Rev 0-1994, Rev 1-1997)
- Probabilistic Seismic Hazard Assessment (PSHA) via Expert Elicitation (1998)
- Staff reviewed and found methodology acceptable

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Design Methodology

- DOE Topical Report YMP/TR 003 NP, *Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain*, Revision 2, August 1997

- DOE Topical Report YMP/TR 003 NP, *Preclosure Seismic Design Methodology for a Geologic Repository at Yucca Mountain*, Revision 3, October 2004

- DOE Letter providing a summary of the preclosure seismic design methodology, August 25, 2005

Proposed DOE Approach

- DOE's proposed approach for compliance with 10 CFR Part 63
  - Design Bases Earthquakes
    - DBGM-1 and DBGM-2
  - NUREG-0800 criteria
  - Seismic Margin Assessment (SMA) for a Beyond Design Basis Ground Motion (BDBGM)

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Staff Feedback to DOE

- NRC Letter to DOE, dated January 24, 2006
- DOE's proposed design basis ground motion, coupled with the proposed design criteria and the codes and standards, appears consistent with 10 CFR 63.112(f)(2).
- The SMA approach is not a substitute for demonstrating compliance with the performance objectives in 10 CFR 63.111(b)(2)
- DOE should consider performing additional supporting analyses to satisfy the performance objectives for Category 2 event sequences, as defined in 10 CFR 63.111(b)(2) and 10 CFR 63.111(c)
- The additional supporting analyses could be performed by using a methodology similar to the one outlined in the American Society of Civil Engineers (ASCE) Standard ASCE 43-05

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Current Status

- NRC-DOE Technical Exchange (June 2006)
- NRC issued the Interim Staff Guidance, HLWRS-ISG-01, in September 2006, to supplement the Yucca Mountain Review Plan (NUREG-1804, Rev. 2, 2003)
- DOE published Revision 5 of the Topical Report YMP/TR 003 TR (June 2007)

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Summary

- 10 CFR Part 63 does not prescribe seismic design requirements for the YM preclosure facilities

- DOE's proposed seismic design methodology, consisting of design bases and seismic margins assessment, requires additional supporting analyses to demonstrate compliance with 10 CFR Part 63

- HLWRS-ISG-01 provides the staff guidance for the review of seismically initiated event sequences

- DOE has adopted the ISG-01 methodology to demonstrate compliance with Part 63

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NRC Interim Staff Guidance, HLWRS-ISG-01, Review Methodology for Seismically Initiated Event Sequences

Mahendra Shah

Briefing to Advisory Committee on Nuclear Waste and Materials

October 16, 2007

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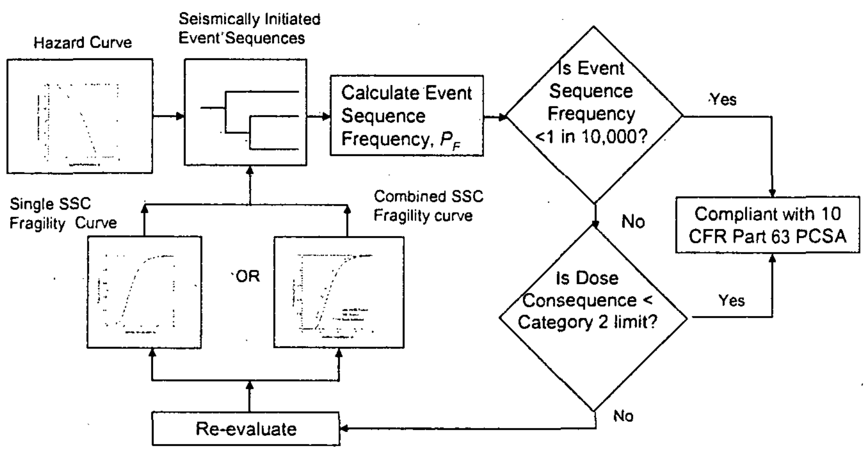
Purpose

- Discuss Interim Staff Guidance (ISG), HLWRS-ISG-01 *Review Methodology for Seismically Initiated Event Sequences,* September 29, 2006
- Compare the methodology to seismic requirements for other nuclear facilities

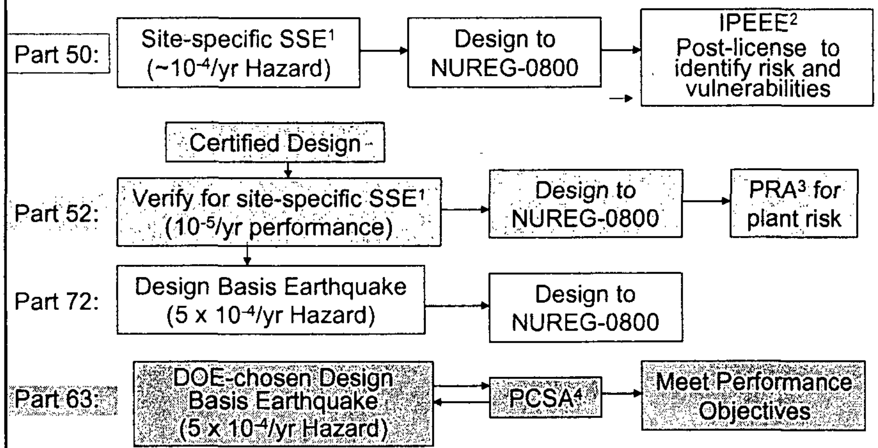
Scope of HLWRS-ISG-01

- Review methodology for seismically initiated event sequences within the overall framework of preclosure safety analysis (PCSA)
- PCSA is a systematic examination of the site; the design; and the potential hazards, initiating events and their resulting event sequences and potential radiological exposures to workers and the public. (63.102(f))
- PCSA is a top-down holistic approach, starting from identification of hazards and potential radiological consequences to identification of important to safety (ITS) structures, systems, and components (SSCs)

Overview of Seismic Design Review Methodology



Comparison of the Seismic Design Process



1 Safe Shutdown Earthquake
2 Individual Plant Examination for External Events
3 Probabilistic Risk Analysis
4 Preclosure Safety Analysis for site-specific seismic hazard
5 Structures, Systems and Components

Note:
Parts 50, 52, 72 – Deterministic design for individual SSC[5]s
Part 63 – Probabilistic for individual event sequences

Summary

- NRC Interim Staff Guidance HLWRS-ISG-01 provides the staff guidance for the review of seismically initiated event sequences, to verify compliance with 10 CFR Part 63
- The ISG-01 methodology to evaluate seismic performance of an SSC ITS is similar to the one outlined in the industry consensus standard, ASCE/SEI 43-05
- Part 63 does not prescribe design requirements, but requires demonstration of performance of SSCs ITS within PCSA event sequences

SEISMIC DESIGN REQUIREMENTS FOR THE MIXED OXIDE FUEL FABRICATION FACILITY (MFFF)

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October 16, 2007
183rd Meeting of the Advisory Committee on Nuclear Waste and Materials (ACNW&M)

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Regulatory Framework

- In 2002, MFFF Construction Authorization Request was submitted by Duke, Cogema, and Stone & Webster (DCS) [A corporate name change occurred in 2006. The new company name is Shaw AREVA MOX Services (MOX Services)]
- NRC evaluated the license application under 10 CFR Part 70, using guidance in NUREG-1718 (Standard Review Plan for the Review of an application for a Mixed Oxide Fuel Fabrication Facility)
  - Risk-informed and performance-based regulation
  - Requires the application to include an integrated safety analysis summary
  - "Baseline Design Criteria" and "defense in depth" are required [see 10 CFR 70.64(a) and (b)], these are stated in broad performance-based language (e.g., "adequate protection")

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Seismic Design Basis

- MOX Services elected to use the same seismic design basis as nearby Vogtle Nuclear Power Plant
  - Regulatory Guide 1.60 horizontal soil surface spectrum scaled to 0.20 g peak ground acceleration
  - Target 1×10^{-4} (~10,000 yr return period) mean annual exceedence probability for ground motions at frequencies of interest (~1-20 Hz)
  - Vertical spectrum is also based on NRC Regulatory Guide 1.60 scaled to 0.20 g peak ground acceleration
  - For soil stability analyses, MOX Services used the bedrock 5×10^{-4} ground motions scaled so that when amplified through the soil, input ground motions produce surface ground motions with 0.20 g peak ground acceleration

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MOX Supported Seismic Design Basis By Comparisons to Other Seismic Criteria

- MOX Services established site-wide design basis earthquake by implementing DOE Standard 1023 (parallels methodology in NRC Regulatory Guide 1.165)
- Design basis earthquake based on DOE performance categories defined in DOE Standard 1020 with PC-3 and PC-4 (mean seismic hazards at 5×10^{-4} and 1×10^{-4} annual exceedence probabilities)
  - Seismic hazard based on Lawrence Livermore National Laboratory (LLNL) and Electric Power Research Institute (EPRI) seismic hazard studies for Central and Eastern United States

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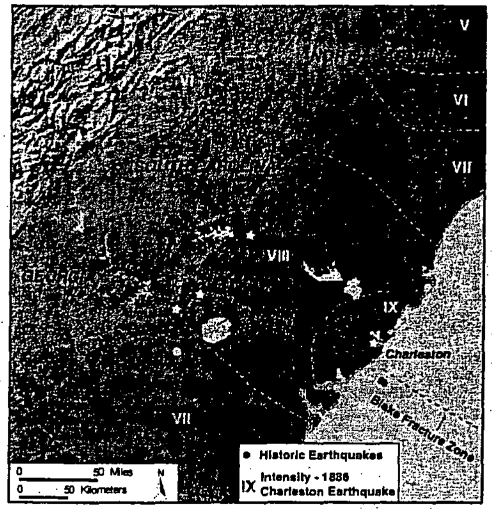
Historic Check: The 1886 Charleston Earthquake



- Based on building damage and paleoliquefaction studies, the 1886 Charleston Earthquake is interpreted as a **M** 7.3 earthquake (MM = IX) at distance of 120 km from the Savannah River site

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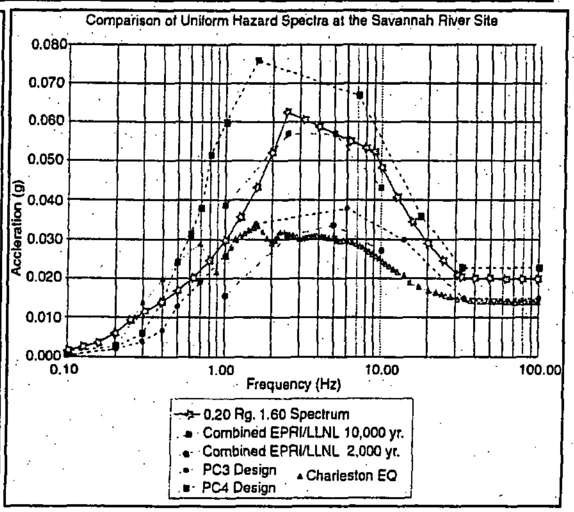
MOX Design and Hazard Spectra

- MOX Services Design based on RG 1.60 spectra scaled to 0.20 g (Vogtle NPP)
- MOX Services Soil stability analyses based on LLNL and EPRI seismic hazard results scaled to site response (using DOE performance categories)
- MOX Services provided "historic check" using the 1886 Charleston Earthquake



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Confirmatory Performance Evaluation

- In response to Staff Request for Additional Information, MOX Services performed limited probabilistic performance evaluation on representative structures, systems, and components (SSCs) important to safety (e.g., offsite power, glove box, building structure)
- MOX Services showed that these SSCs maintained their intended safety functions at 1×10^{-5}/yr failure probability or better, consistent with guidance in NUREG-1718
- MOX Services applied the ASCE 43-05 methodology to compute failure probabilities of these SSCs

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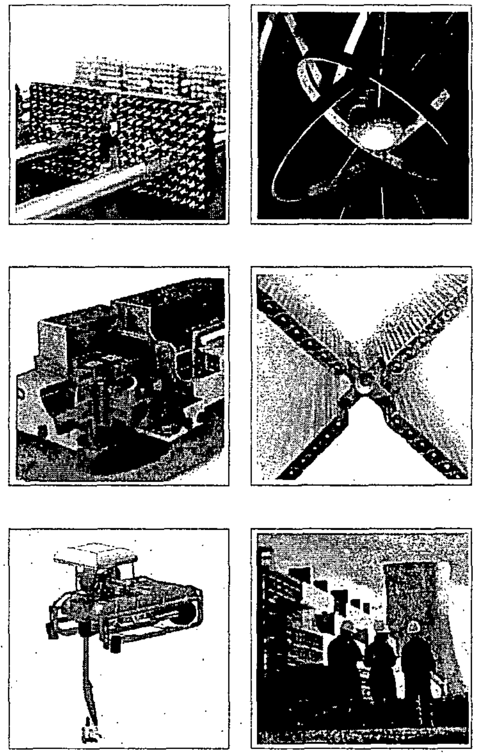
Summary of Staff Evaluation is in NUREG-1821 (March, 2005)

- Bedrock Seismic Hazard: Application of LLBL and EPRI hazard results is appropriate
- Site Response: Site response models, based on site-specific soil data, are adequate
- Seismic Design:
  - Regulatory Guide 1.60 spectra scaled to 0.20 g peak ground acceleration envelopes uniform hazard spectrum and Charleston Earthquake "historic check" at frequencies of interest
  - Probabilistic performance evaluation shows that critical systems, structures, and components consistent with performance objectives

Commercializing Nuclear Pyroprocessing Technology



Presentation to NRC's ACNW&M
Eric P. Loewen, Ph.D.
Earl F. Saito, Ph.D.
GE-Hitachi Nuclear Energy

October 2007

Imagine a solution to nuclear waste...

GE-H's overview of recycling nuclear fuel

GNEP Performance

... a confluence of the past to forge the future

Environmental performance

Operating performance

1	2	3	4
Atoms for Peace	Integral Fast Reactor Program	Regulatory &Technology Path Forward	Build a "model home"
1953	[illegible]	Now	Future

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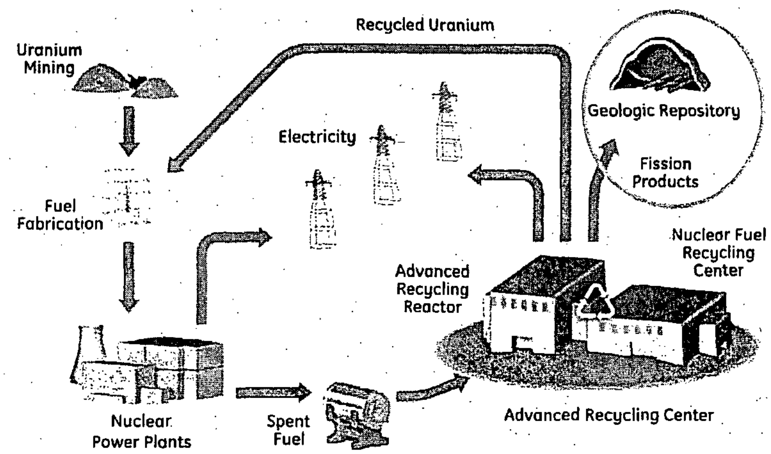
GE-H solves nuclear waste problem with Advanced Recycling Center (ARC)



PRISM
(Advanced Recycling Reactor)

- Simple operation
- Highly reliable and passively safe
- Simplified O&M
- Modular/scalable deployment

Electro-refining
(Fuel Recycling Center)

- Ideal for fast reactors and metal fuel
- Removes all actinides together
- Process LWR SNF using proven technology
- Low environmental impact

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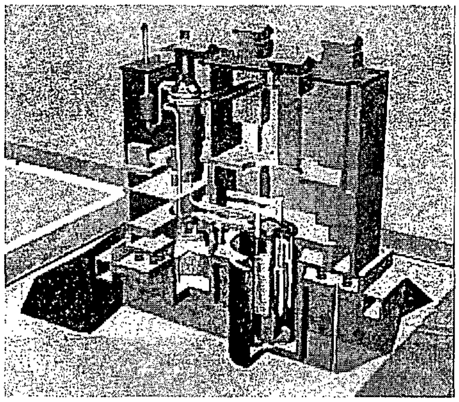
Advanced Recycling Reactor … PRISM

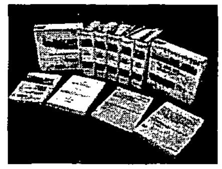


✓ Advanced Conceptual Design

- Already paid for by USG
- Available today

✓ NRC "…no obvious impediments to licensing…"

- Prudent starting point



1981-1984 GE Program
- **GE funded**
- Innovative design approaches

1985-1987 PRISM
- **DOE funded $30M**
- Competitive LMR concepts

1988 PRDA
- **DOE funded $5M**
- Continuing trade studies

1989-1995 ALMR
- **DOE funded $42M**
- Preliminary design
- Regulatory review
- Economics
- Utility advisory board
- Commercialization
- Tech development ($107M additional)

1995-2002 S-PRISM
- **GE Funded**
- Improved economics
- Actinide burning scenarios

2007-2014 GNEP
- Demo reactor
- Actinide burning
- Commercial
- Best practices
- Advanced power conversion cycle

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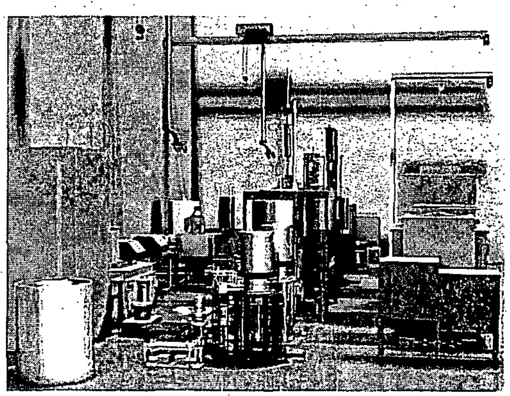
Electrorefining Development



✓ NAS Committee Findings

- No technical barriers for electrometallurgical processing of EBR-II fuel
- DOE should seriously consider continued development as an option to aqueous treatment of uranium oxide spent nuclear fuel

✓ Prudent GNEP starting point

- Domestic solution available today

1964-1969 Melt Refining
- **AEC Funded**
- Innovative design approaches

1984 IFR Program
- **DOE funded**
- Prove metal fuel

~1990 Japan
- ***Japanese Support***
- Contributed $40M
- Committed $60M
- Contributed $6M for LWR oxide reduction

1989-1995 IFR Ends
- **Program Terminated**
- EBR-II shut down
- EBR-II 30 years of successful operation

1995-1999 EBR-II Fuel
- **EBR-II Fuel Treatment**
- Requires treatment
  - ➢Enrichment
  - ➢Na bond
  - ➢Pyrophoric
  - ➢RCRA
- DOE ROD
- NAS review

2000-2007 GNEP
- EIS completed
- Processing EBR-II fuel currently
- 3T processed
- Best practices

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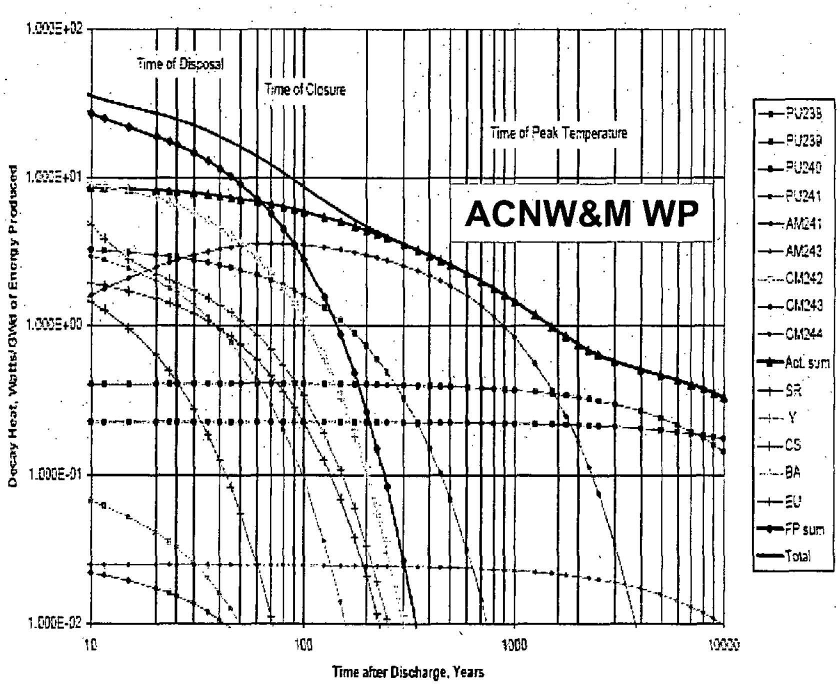
Why is GE-H Nuclear Energy pursuing pyroprocessing?

- Environment
- Economics
- Engineering

Heat load is important.

... Environment



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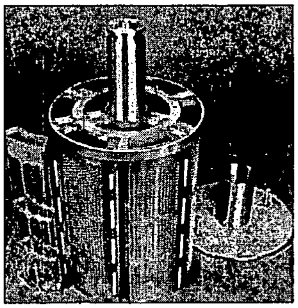
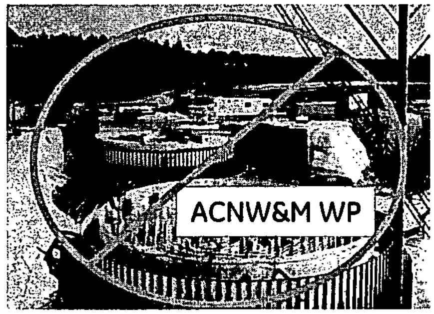
Why the dry process?

... Environment





Dry Recycle (Pyro) Process

- ✓ Simple to build and operate
- ✓ U and TRU separation based on electro-chemical potential– no pure Pu
- ✓ Shorter half life and heat in waste
- ✓ Achieves economies of scale through modularity and duplication
- ✓ Produces positive cash flow when combined with PRISM, busbar cost of $0.029/kWhr (1996 ALMR)

Wet Process

- Wet chemistry using acid process creates waste issues
- No place for MOX fuel after used in LWR
- Difficult for legacy SNF
- France, UK and Japan wet processing is subsidized
- Japan implementation illustrates difficulties of process

Fuel Cycle Facility for 1400 MWe Fast Reactor

... Economics

	Pyroprocessing	Aqueous Processing
<u>Size and Commodities</u>		
Building Volume, ft^3	852,500	5,314,000
Volume of Process Cells, ft^3	41,260	424,300
High Density Concrete, cy	133	3,000
Normal Density Concrete, cy	7,970	35-40,000
<u>Capital Cost, $million (1986$)</u>		
Facility and Construction	62.6	178.6
Equipment Systems	29.8	298.6
Total	92.4*	477.2**

**ANL-AFR-25 report*
***ORNL/TM-9840*

Weapons Usability Comparison

... Engineering

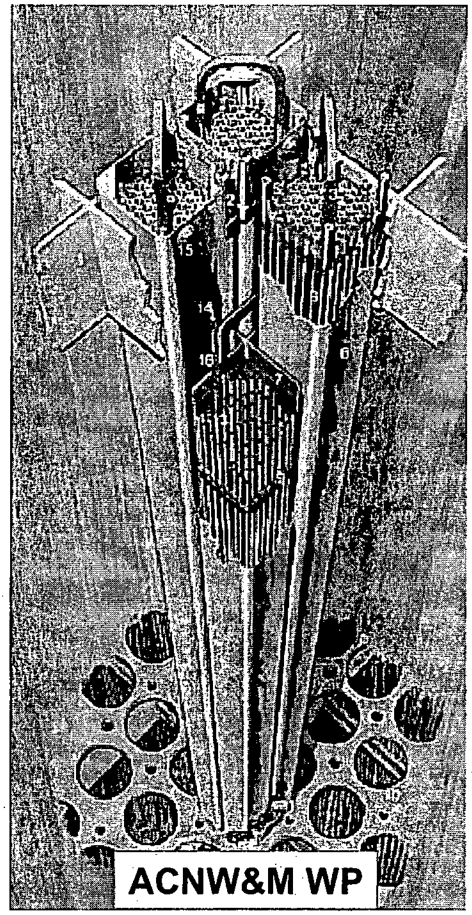
	Weapon Grade Pu	Reactor Grade Pu	IFR Grade Actinide
Production	Low burnup PUREX	High burnup PUREX	Fast reactor Pyroprocess
Composition	Pure Pu 94% Pu-239	Pure Pu 65% Pu-fissile	Pu + MA + U 50% Pu-fissile
Thermal power W/kg	2 - 3	5 - 10	80 - 100
Spontaneous neutrons, n/s/g	60	200	300,000
Gamma radiation r/hr at ½ m	0.2	0.2	200

Process Inputs

- LWR bundle
- FR bundle
- Flow sheet

Composition of Discharged BWR Fuel

95% uranium
4% fission products
1% TRU



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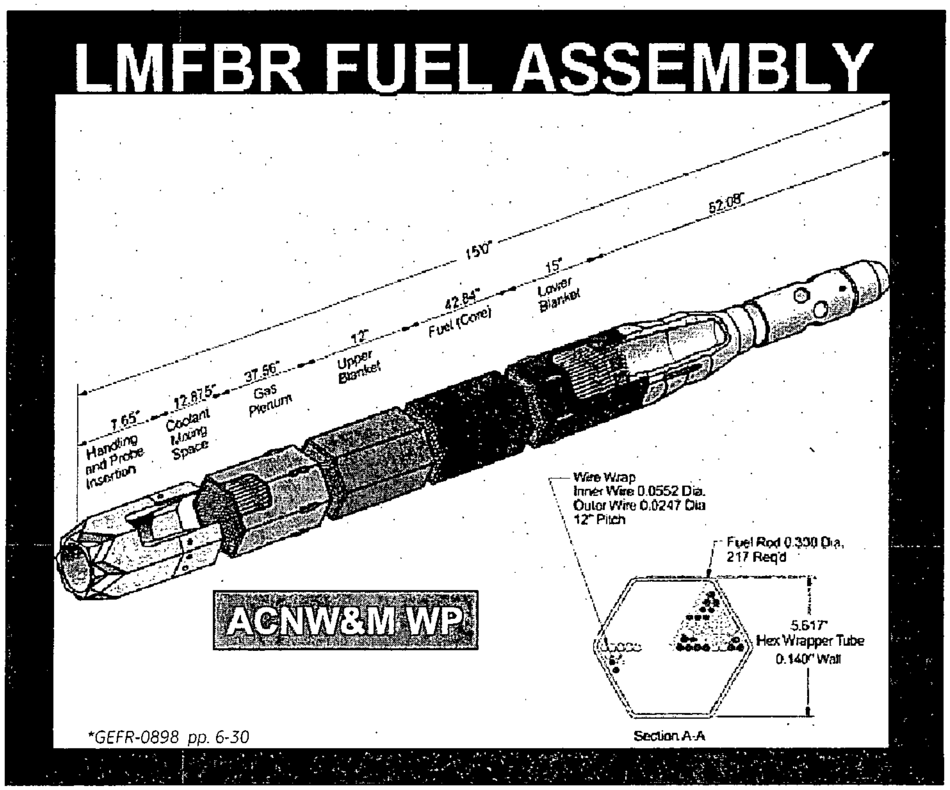
PRISM Fuel Bundle



*GEFR-0898 pp. 6-30

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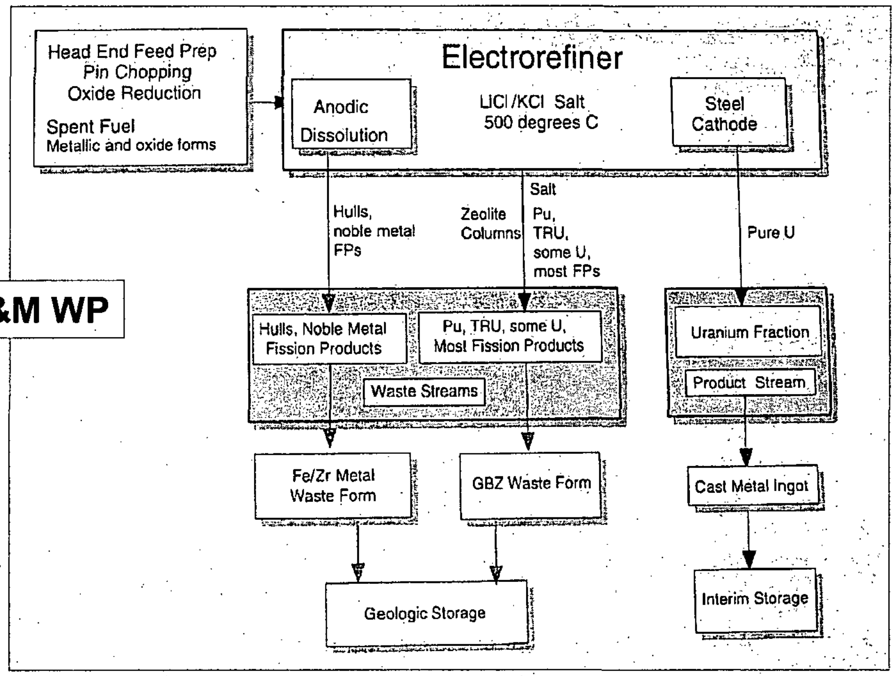
Pyroprocessing Block Flow Diagram



ACNW&M WP

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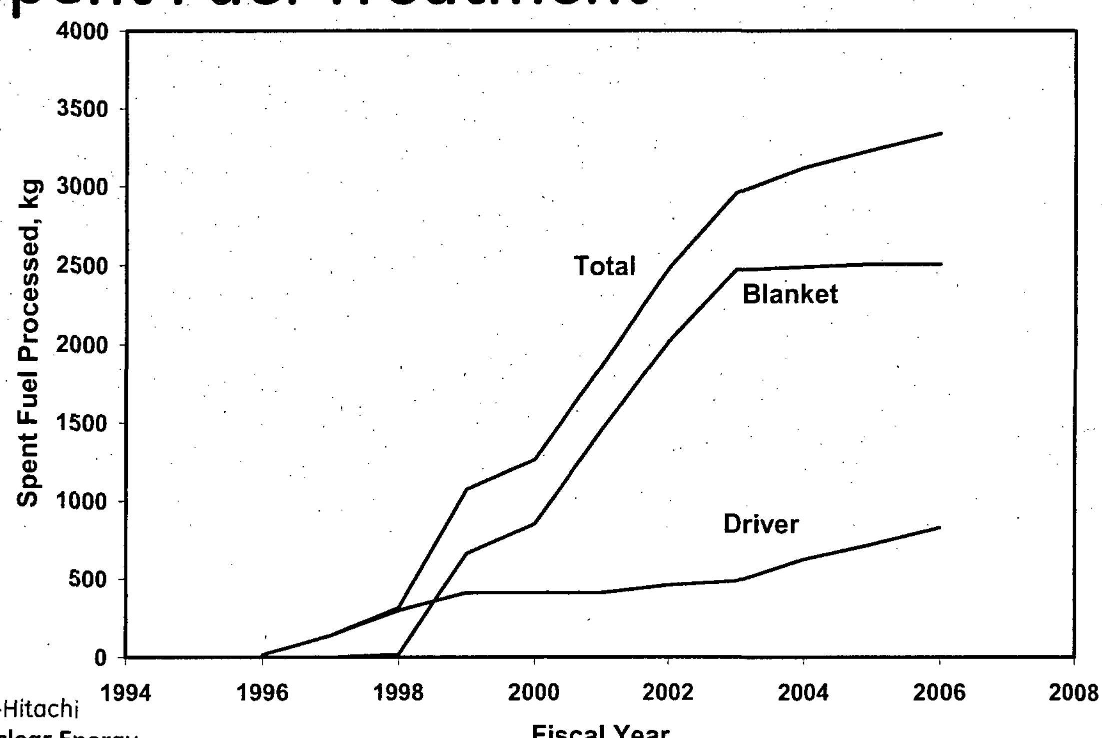
NAS Committee . . .
'no technical barriers for processing of EBR-II fuel'

Cumulative Quantities of EBR-II Spent Fuel Treatment



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History of Pyroprocessing

- Process
- Performance
- Deficiencies

Melt-refining -- the beginning . . .

Process

- Spent fuel slugs melted in CaO-coated ZrO_2 crucible
- FPs Xe, Kr, I, Br, Cs, and Cd – collection in fume trap
- FPs Y, Ba, Sr, and rare earths – capture in crucible oxide
- Melt-refined ingot fissile fuel + noble metal FPs
  - ❖ Injection-cast into fuel and returned to reactor

Performance

Melt-refining closed the EBR-II fuel cycle from 1964-69

- ~30,000 irradiated fuel pins were recycled
- ~2 months from discharge to reactor reload
- Throughput 100 kg/month, peak 245 kg/m (~3 tons/yr)

Melt-refining had two deficiencies

1) Noble metal FP could not be removed
   - ✓ Acceptable at 1% burnup
   - ✓ At 20% burnup (demonstrated), noble metal fission products must be removed

2) Melt-refining could not recover plutonium (or other actinides) from the blanket for actinide fuel fabrication

Pyroprocessing developed during the ALMR program solves both deficiencies

Key Attributes of Pyroprocessing

- All actinides are recovered together
  - No need for additional partitioning processes
  - A major non-proliferation advantage
- Ideally suited for fast reactor metal fuel recycle: compact equipment results in drastically improved economics
- No liquid organic waste
- No need for SNF storage prior to recycling

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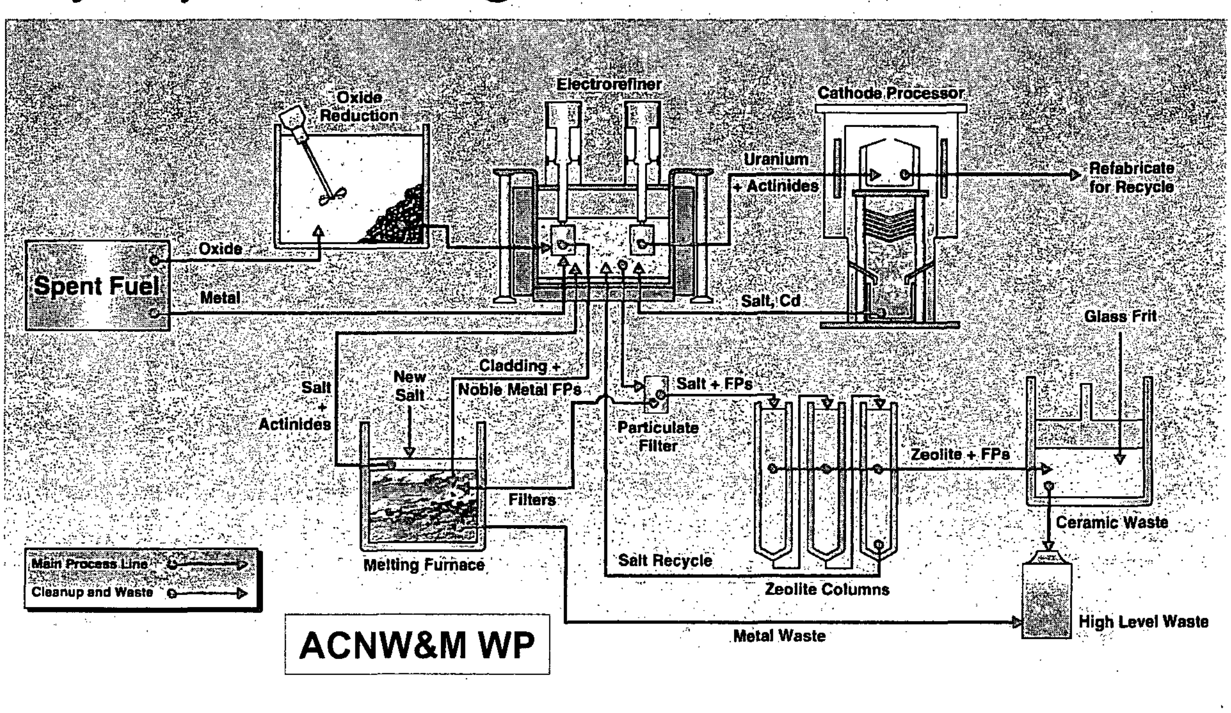
Pyroprocessing Flow Sheet

- Components
- Performance
- Deficiencies

Pyroprocessing Flowsheet



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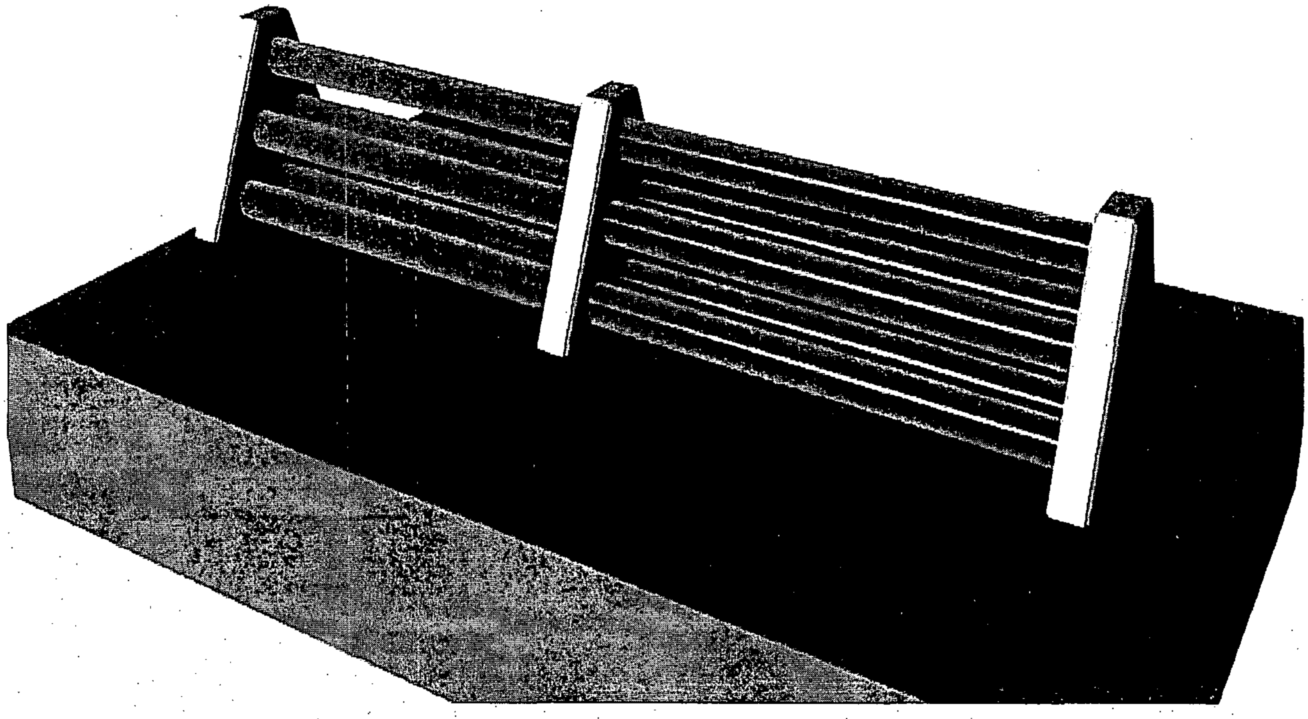
Animation of pyroprocessing



Pyroprocessing for LWR Spent Fuel

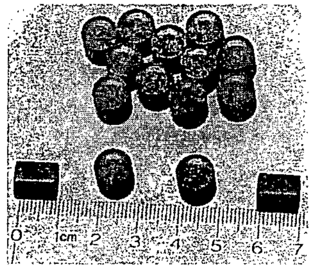
- Electrorefining has been demonstrated for fast reactor metal spent fuels
- For LWR spent fuel application, oxide-to-metal reduction front-end step is required:
  - ✓ Li reduction process was developed in early 1990s
  - ✓ Eletrolytic reduction process more promising
- For economic viability, the electrorefining batch size has to be increased: this should be straightforward with planar electrode concept

Electrolytic Oxide Reduction Process

- Argonne developed an innovative electrochemical process for converting spent fuel oxides to metals
  - ✓ Anode process produces oxygen gas that is swept from cell

    $$2\,O^{2-} = O_2\,(g) + 4\,e^-$$
  - ✓ Cathode process yields metallic product suitable for electrorefining

    $$MO_x\,(s) + 2xe^- = M\,(s) + x\,O^{2-}$$
  - ✓ LiCl @650°C solvent
- Argonne is also developing conductive inert ceramic anodes for use in large-scale electrolytic cells



Urania feed material

Reduced product

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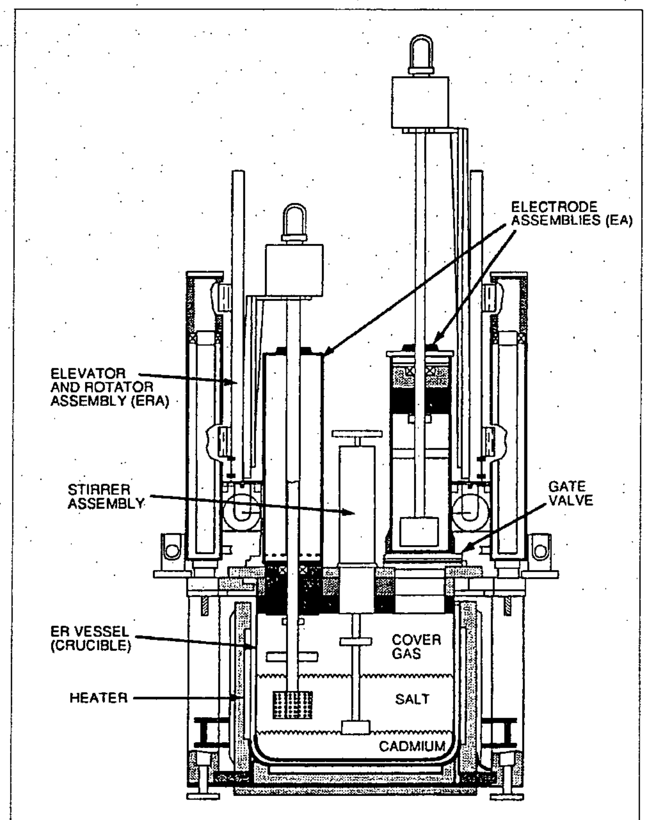
Argonne

Electrorefiner



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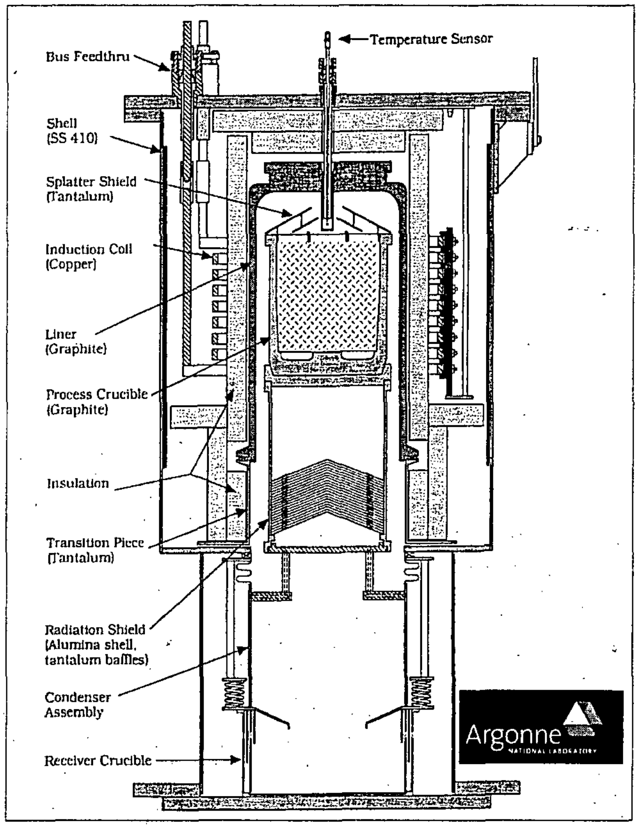
Argonne

Cathode Processor



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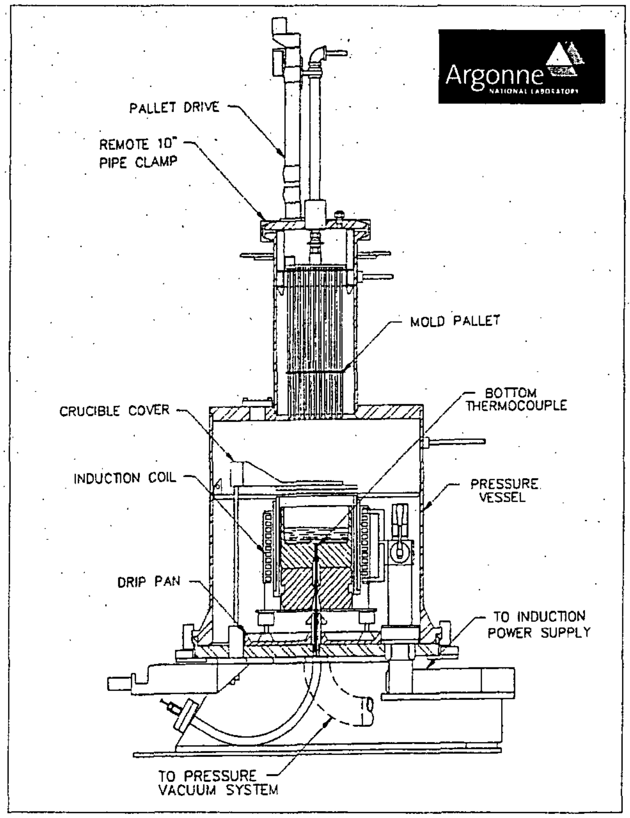
Injection Casting Furnace



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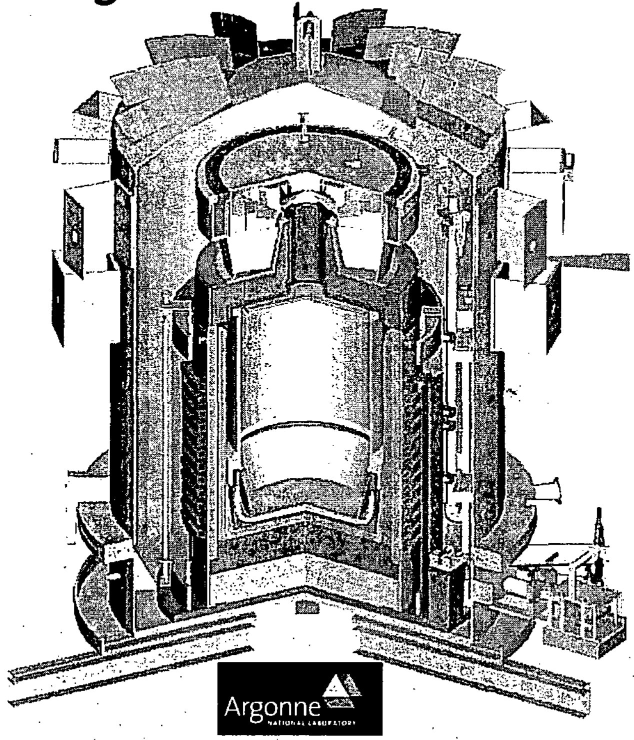
Metal Waste for Furnace
(90 kg metal ingot)



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Pyroprocessing Wastes

- Product streams
- Waste form
- R&D

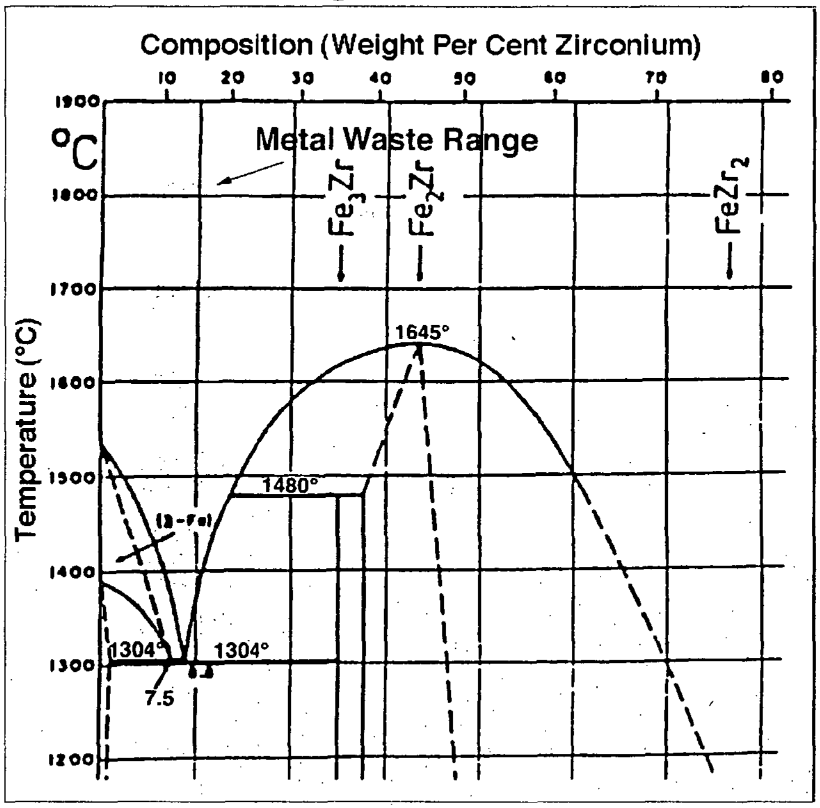
Product Streams

- Most fission products form stable chlorides that remain in the salt phase and process into a ceramic waste form
- Noble metal fission products remain in the anode basket and processed into a metal waste form along with cladding hulls
- Only actinides are subject to electro-chemical transport, but the process is inherently a low decontamination process, and some rare earth fission products may also get deposited along with the actinides

Metal Waste Form

- Following electrorefining, the anode basket that contains stainless cladding hulls, fuel matrix alloy zirconium, noble metal fission products (including technetium), and adhering salt is heated in the metal waste form furnace to distill the adhering salt, and then heated to higher temperature to consolidate the metal waste form
- For fast reactors, the base alloy for metal waste will be stainless steel with zirconium concentration in the range of 5-20% to form a low melting eutectic
- For LWRs, the base alloy will be zirconium with about 15% iron, which forms even lower temperature eutectic on the other side of the Fe-Zr phase diagram

Fe-Zr Phase Diagram



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Ceramic Waste Form

- Most of fission products other than noble metals accumulate in the salt phase. When saturated, salt is passed through zeolite column.
- Fission product cations are adsorbed onto zeolite by ion exchange or occluded into molecular cages of zeolite structure.
- Zeolite with fission products immobilized is consolidated into a monolithic form by sintering at high temperatures combined with borosilicate glass as binder.
- At high temperatures, zeolite is converted into sodalite, a stable, naturally occurring mineral.

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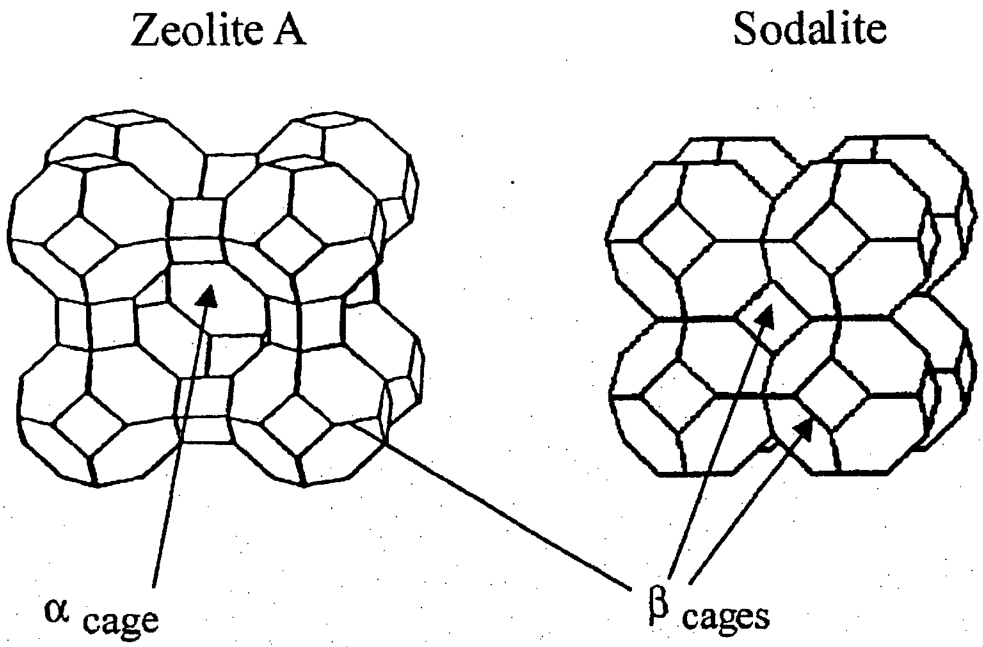
Molecular Cages of Zeolite & Sodalite



Path Forward

- 2001 Energy Policy
- ANL Development
- ALMR Development
- Commercialization

National Energy Policy -- May 2001

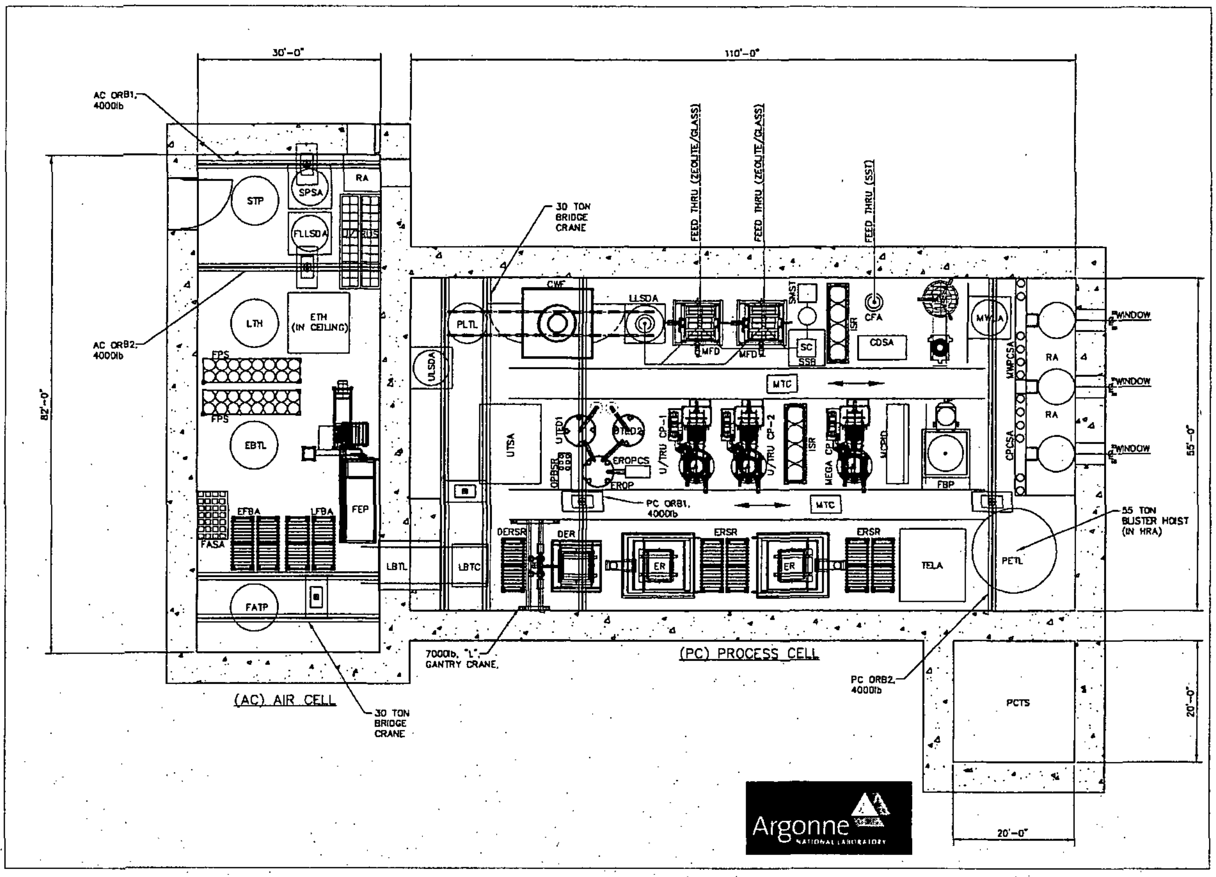
"The NEPD Group recommends that, in the context of developing advanced nuclear fuel cycles and next generation technologies for nuclear energy, the United States should reexamine its policies to allow for research, development and deployment of fuel conditioning methods (such as pyroprocessing) that reduce waste streams and enhance proliferation resistance. In doing so, the United States will continue to discourage the accumulation of separated plutonium, worldwide."

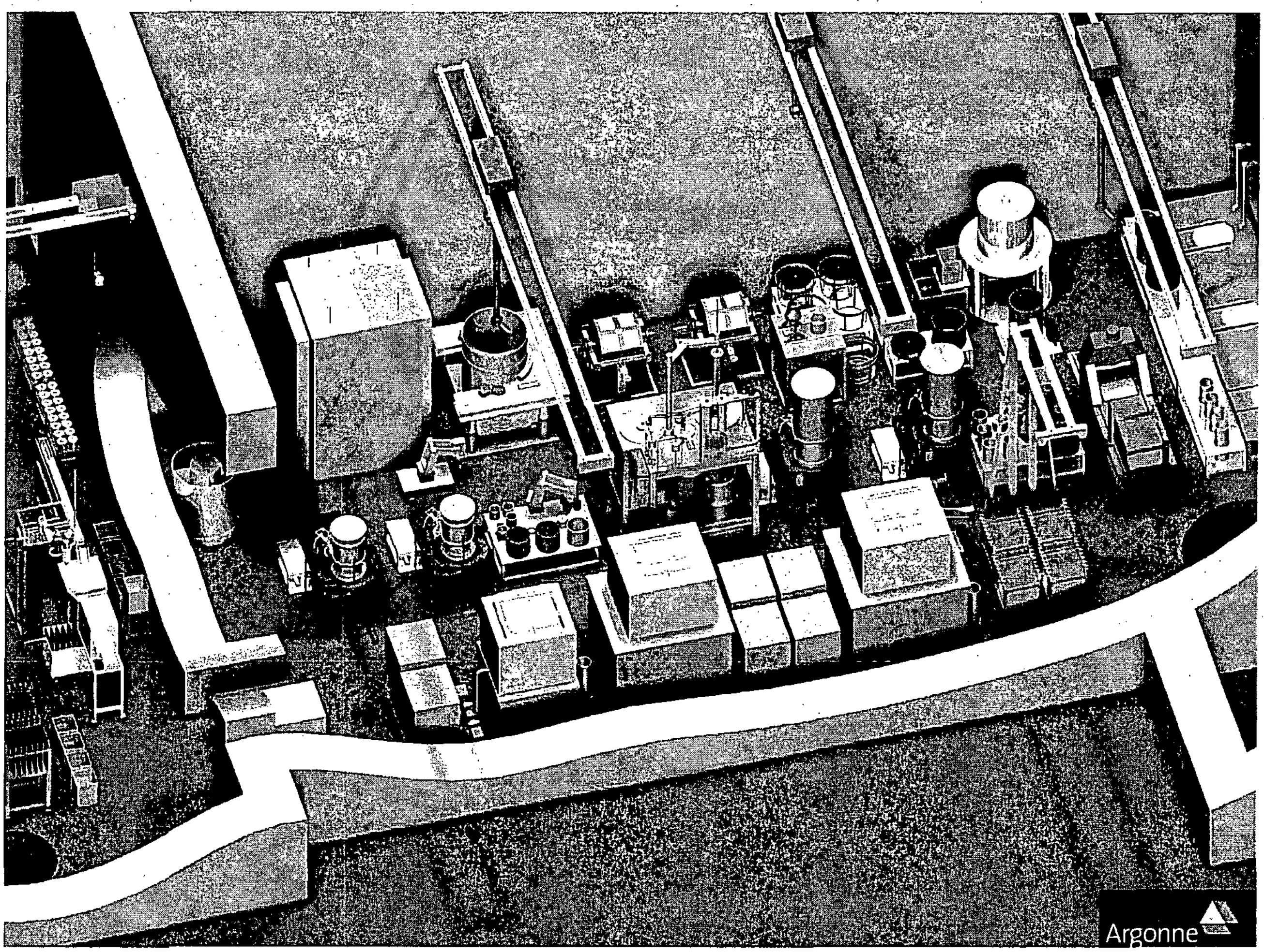
Conceptual design for 100T/yr throughput facility

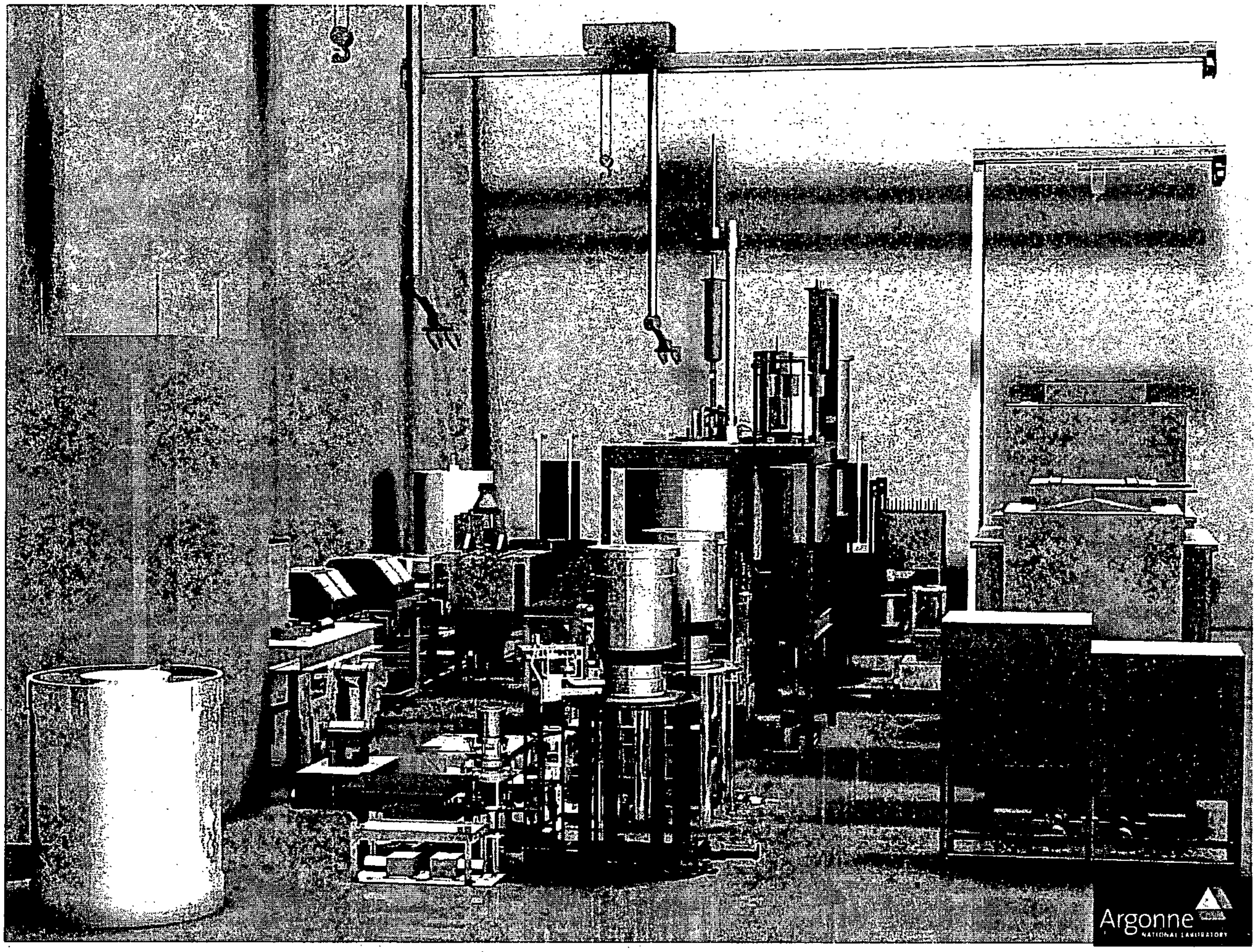
Argonne National Laboratory developed:

- ✓ Detailed flowsheet
- ✓ Equipment concepts
- ✓ Operational process model

ANL design for 100T/yr facility





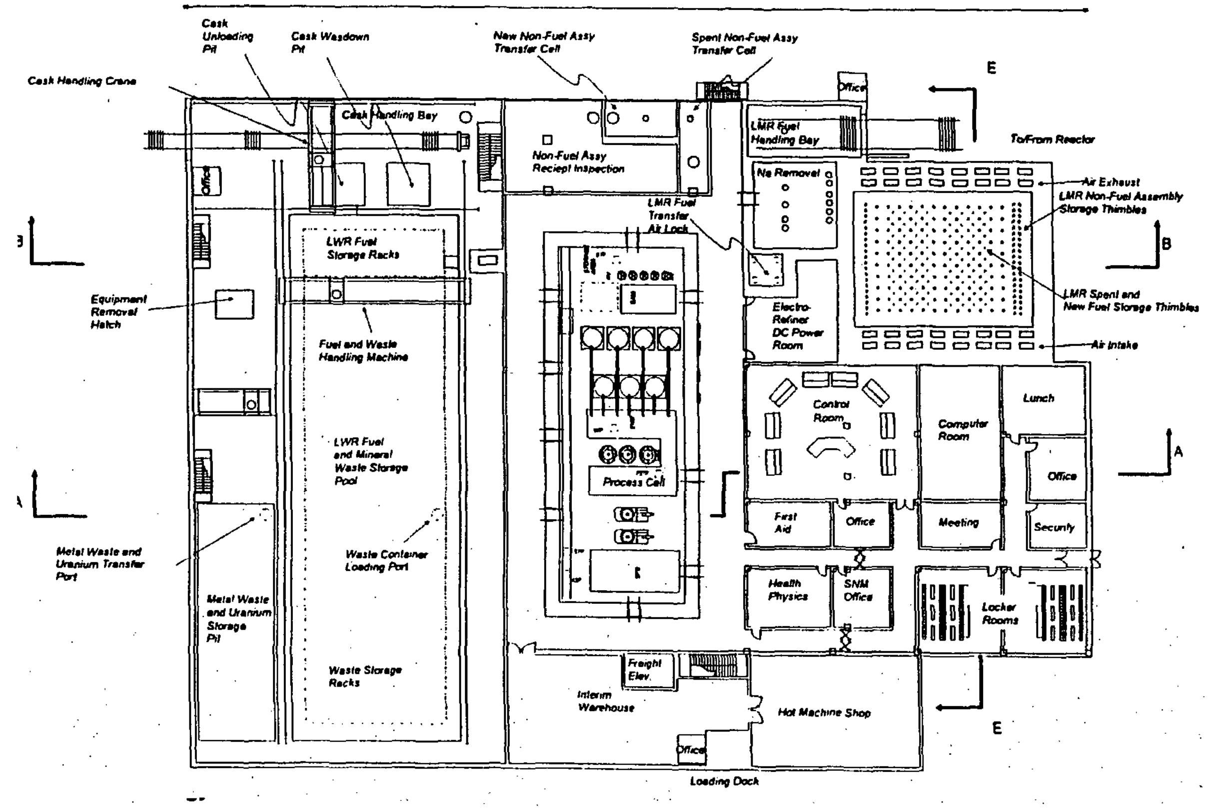


ALMR Program

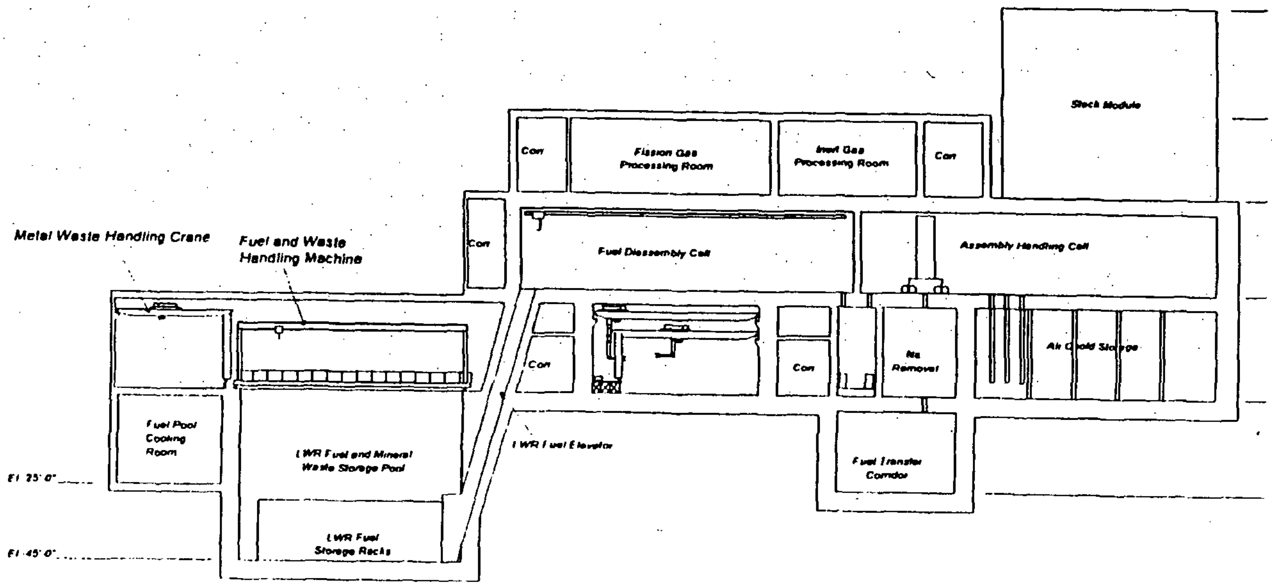
Burns and Roe report to GE (GEFR-0942):

- Detailed flowsheet and material balances
- Conceptual capital and operating cost estimates
- Complete facility conceptual design
- Four plant concepts developed:
  1) *Centralized Fuel Cycle Facility ~170 MTHM/yr (LMR only)*
  2) *Collocated Fuel Recycle Facility ~22 MTHM/yr (LMR only)*
  3) *LWR Spent Fuel Process Facility ~ 2,200 MTUO2/yr*
  4) *Spent Fuel Recycle Facility*
     - *~915 MTUO2/Yr (LWR peak)*
     - *~50 MTHM/yr LMR*

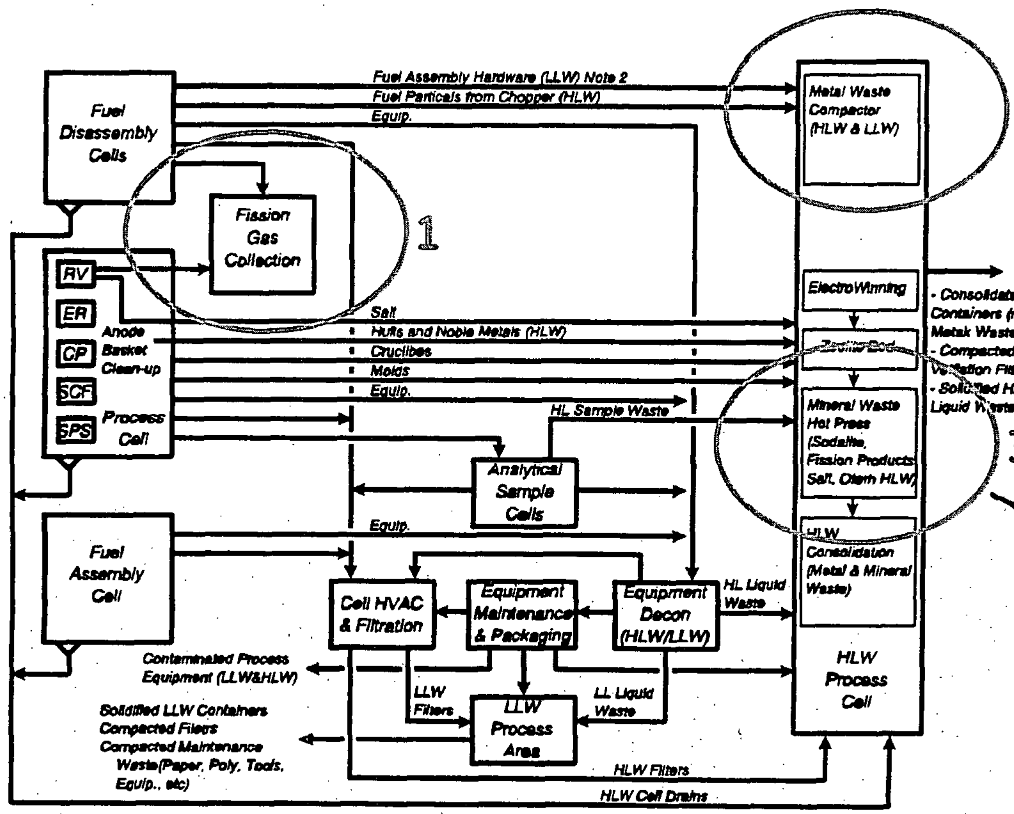
Spent Fuel Recycle Facility El. 0'-0"



Spent Fuel Recycle Facility (side view)



Waste Processing Systems

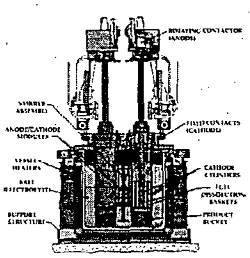


Building the Nuclear Fuel Recycling Center

Conceptual Design

Status: 70% Complete
Design: Electrorefiner

- ✓ Continuous or batch process
- ✓ Use advanced concepts from ANL, Japan, Russia, and Korea



Path 1

Licensing

- ➢ Use existing Wilmington Part 70 LWR Fuel License
- ➢ Conduct Integrated Safety Analysis (ISA)

Path 2

Simulation

- ➢ Build deployment simulation model
- ➢ Start design optimization

Path 3

Component Testing

- ➢ Fabricate select components
  - ❖ Electrorefiner
  - ❖ Cathode processor
  - ❖ Fuel casting equipment
- ➢ Test components

NFRC Deployment

- Follow EBRII fuel disposal system
- Integrate simulation into design process

Benefits:

- Reduced time for prototypic separations
- Immediate ability to license under Part 70 at Wilmington, NC facility
- Rapid completion of ISA
- Takes advantage of existing GE processes
- Optimize design through iteration

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MC&A

DER Demonstration

- ✓ Work will follow GE-H fundamental nuclear material control plan for Material Control and Accountability
- ✓ Processes and procedures will be developed to allow for MC&A in hot cell conditions

NRC License Plan

Use Wilmington license for testing of electro-reducer

- ✓ Based on less than 5% enrichment, but analysis will envelope SNF that will be used in Morris
- ✓ Testing based on UO_2/surrogate feed
- ✓ Build a system for uranium-only processing

Post testing activities

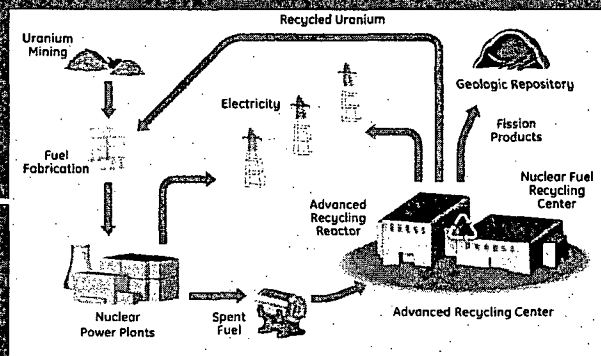
- ✓ If necessary, develop NUREG/standards
- ✓ Report results to ACNW&M

Deploy under 10CFR70 'testing' equipment

- ✓ Morris, or
- ✓ other sites using spent nuclear fuel as feed

GEH Advanced Recycling Center

- Integrated solution
- Available technology
- Excellent site



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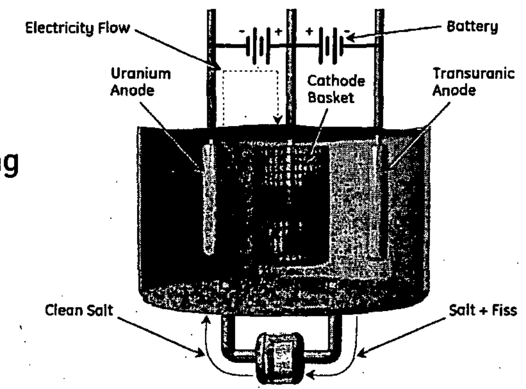
Back up

Nuclear Fuel Recycling Center

- ✓ **Based on electrorefining technology developed by Argonne National Laboratory** – proliferation resistant
- ✓ **Produces three products:**
  Uranium, TRU and FP
- ✓ **Fabricates fuel for the Advanced Recycling Reactor**
- ✓ **Design features include:**
  - **No liquid waste** – avoids negative environmental impact
  - **Modular/scalable** – rapid construction
  - **Factory built** - high-quality construction
- ✓ **Extensive component testing**
- ✓ **Used by metals processing industries for over a century**

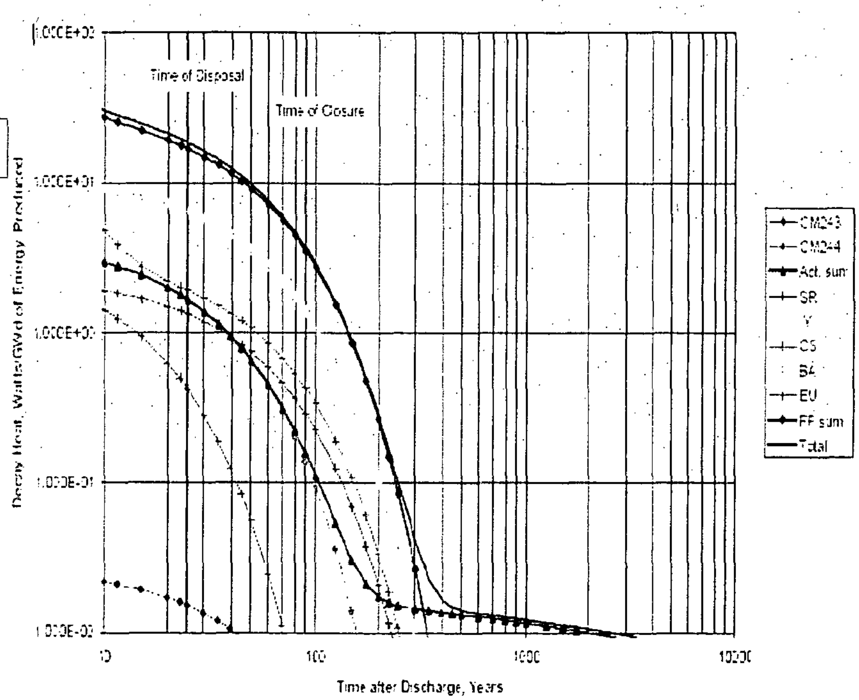


Actinide Removal Reduces Heat Load

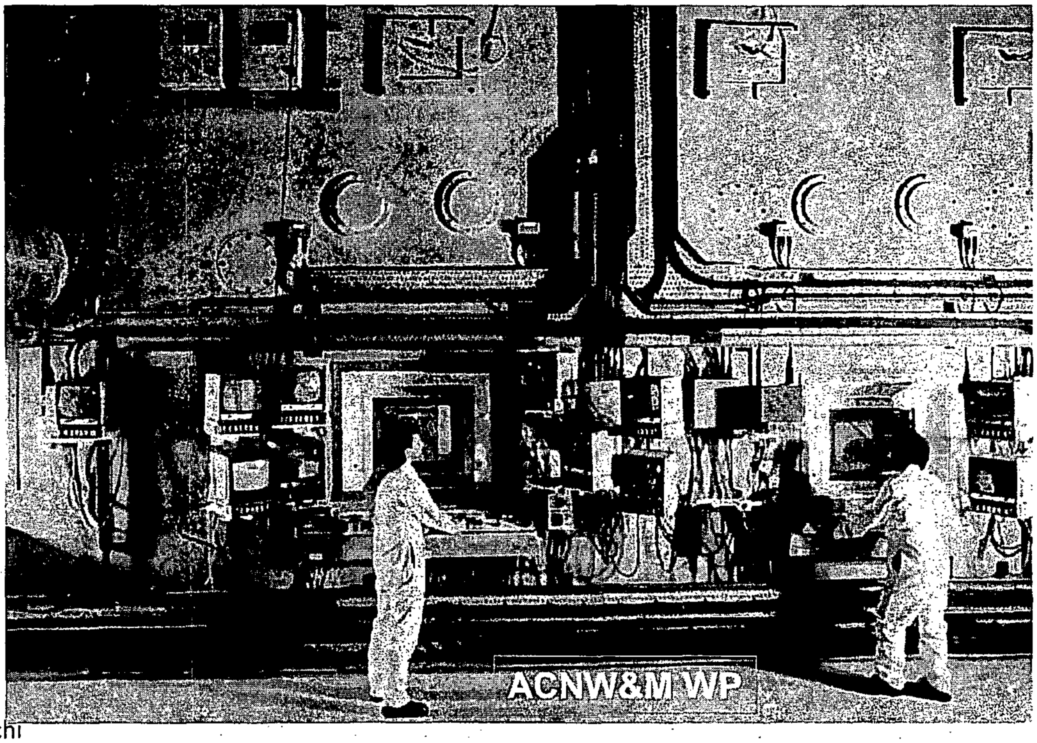
... Environment

DRAFT REPORT FOR EXTERNAL REVIEW

ACNW&M WP



Current Hot Cells



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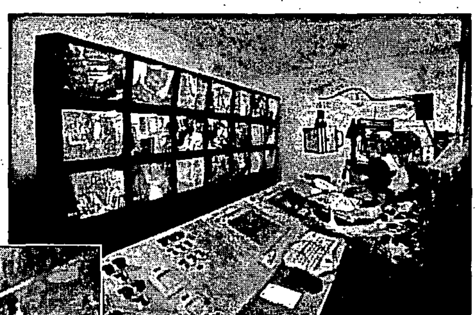
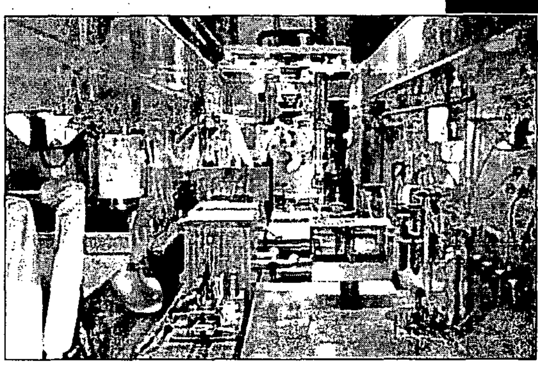
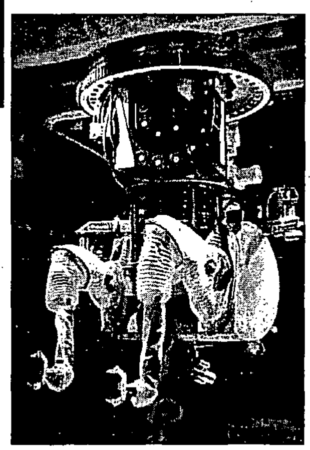
Spallation Neutron Source provides model of modern hot cell





The target service bay, looking toward the mercury process at the west end. The dual-arm servomanipulator is visible at the far end of the cell.



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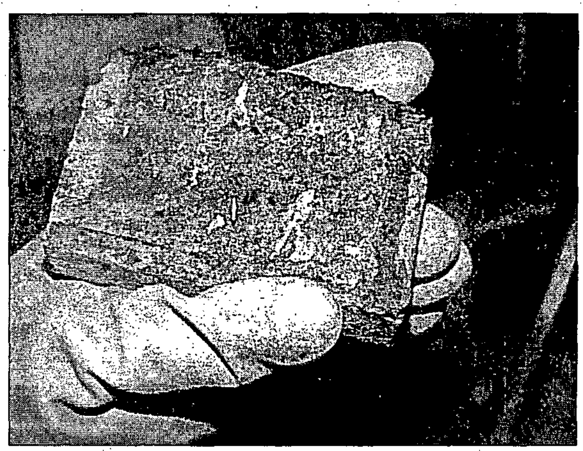
http://www.istcorp.com/documents/SNSOakridge.pdf

Free Energies of Chloride Formation at 500°C, -kcal/g-eqCl

Elements that remain in salt (very stable chlorides)		Elements that can be electrotransported efficiently		Elements that remain as metals (less stable chlorides)	
$BaCl_2$	87.9	$CmCl_3$	64.0	$ZrCl_2$	46.6
CsCl	87.8	$PuCl_3$	62.4	$CdCl_2$	32.3
RbCl	87.0	$AmCl_3$	62.1	$FeCl_2$	29.2
KCl	86.7	$NpCl_3$	58.1	$NbCl_5$	26.7
$SrCl_2$	84.7	UCl_3	55.2	$MoCl_4$	16.8
LiCl	82.5			$TcCl_4$	11.0
$CaCl_2$	80.7			$RbCl_3$	10.0
$LaCl_3$	70.2			$PdCl_2$	9.0
$PrCl_3$	69.0			$RuCl_4$	6.0
$CeCl_3$	68.6				
$NdCl_3$	67.9				
YCl_3	65.1				

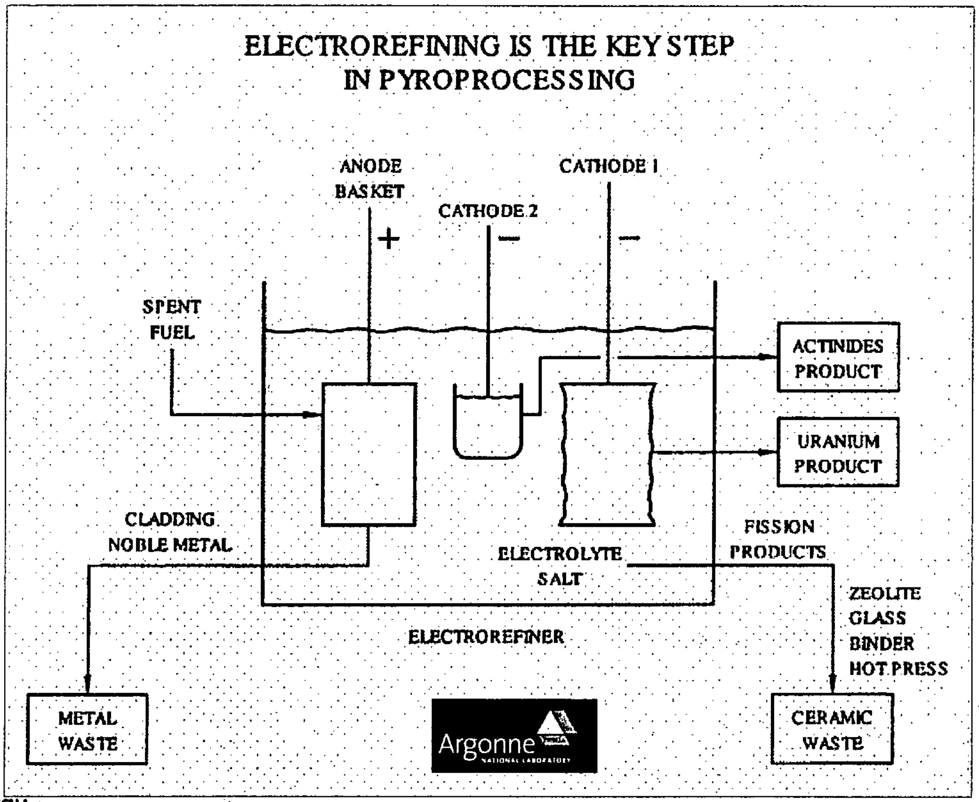
Reduction Status of Oxide Process

- Laboratory-scale cell studies
  - ✓ Complete reduction of UO_2 (>99.7%) routinely demonstrated up to the kilogram scale
  - ✓ Complete reduction of UO_2–PuO_2 demonstrated at the gram scale
  - ✓ Alkali and alkaline earth fission products have no effect on conversion process
  - ✓ No 'show stoppers' identified in other fission product studies (e.g., lanthanides, iodine)
- High-capacity cell studies
  - ✓ Kilogram-scale demonstrations of process yielded high current efficiency and efficient oxygen gas removal from cell
  - ✓ Reduction rates are very good; cells designed to collect fundamental data



Metallic uranium product from high-capacity reduction cell test

Electrorefining is the Key Step



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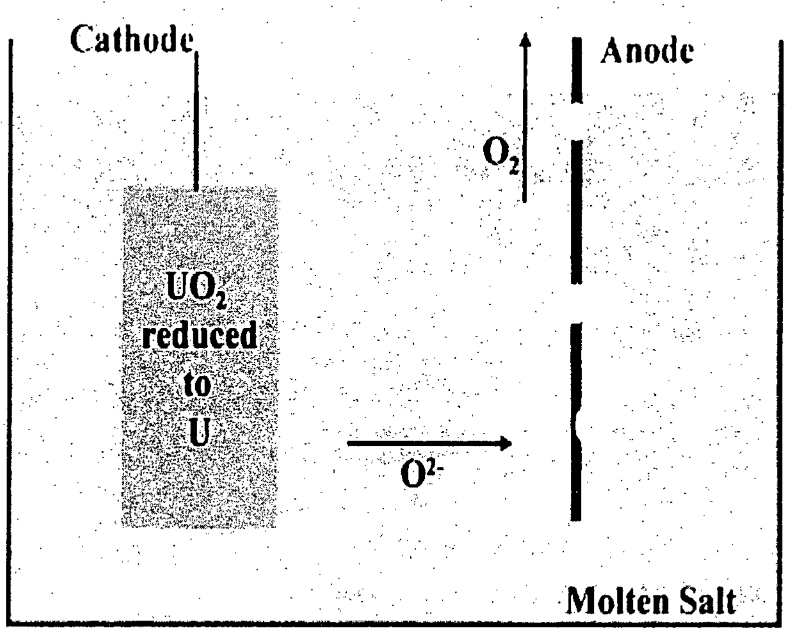
Electrolytic Reduction Process



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