

ORIGINAL

**UNITED STATES OF AMERICA**  
**NUCLEAR REGULATORY COMMISSION**

**Title:            BRIEFING ON HIGH-BURNUP FUEL ISSUES -  
PUBLIC MEETING**

**Location:        Rockville, Maryland**

**Date:            Tuesday, March 25, 1997**

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1 UNITED STATES OF AMERICA  
2 NUCLEAR REGULATORY COMMISSION

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4 BRIEFING ON HIGH-BURNUP FUEL ISSUES

5 \*\*\*

6 PUBLIC MEETING

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9 Nuclear Regulatory Commission  
10 Room 1F-16  
11 One White Flint North  
12 11555 Rockville Pike  
13 Rockville, Maryland  
14

15 Tuesday, March 25, 1997  
16

17 The Commission met in open session, pursuant to  
18 notice, at 10:04 a.m., the Honorable SHIRLEY A. JACKSON,  
19 Chairman of the Commission, presiding.

20 COMMISSIONERS PRESENT:

21 SHIRLEY A. JACKSON, Chairman of the Commission  
22 KENNETH C. ROGERS, Member of the Commission  
23 EDWARD McGAFFIGAN, JR., Member of the Commission  
24  
25

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1 STAFF AND PRESENTERS SEATED AT THE COMMISSION TABLE:

2

3 JOHN C. HOYLE, Secretary

4 KAREN D. CYR, General Counsel

5 JOE CALLAN, EDO

6 DR. CARL PAPERIELLO, Director, NMSS

7 THOMAS KING, Deputy Director, Division of Systems

8 Technology, RES

9 GARY HOLAHAN, Director, Division of Systems Safety and

10 Analysis, NRR

11 RALPH MEYER, Senior Technical Advisor, RES

12 HAROLD ORNSTEIN, Reactor Analysis Branch, AEOD

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

[10:02 a.m.]

CHAIRMAN JACKSON: Good morning. I am pleased to welcome members of the Staff to brief the Commission on high-burnup fuel issues.

Greater economic competitiveness is causing the nuclear power industry to pursue various changes. Among those are longer fuel cycles and high burnup fuels. This morning the Staff will discuss its activities in the high-burnup fuel area and describe any safety concerns raised by information derived from reactivity insertion experimental test results in other countries including France, Russia, and Japan.

The Staff will describe how these experiments are being followed up and what impact they have on issues of safety in U.S. nuclear reactors.

The Commission is interested in hearing how the Staff is integrating information from research including the results of tests and analysis done by the international community and domestic operating experience and how this information is being used to ensure that plants are operating safely and in conformance with their licensing basis.

The Commission is also interested in hearing about the appropriateness of our current fuel damage criteria for

1 reactivity insertion events.

2 My understanding is that the Staff will discuss  
3 the status of the research program on high-burnup fuel and  
4 the adequacy of our codes to account for high-burnup  
5 effects.

6 The research program to date has focused on high-  
7 burnup fuel response to reactivity insertion accidents, but  
8 there are other considerations. For example, high burnup  
9 fuel response under design basis analysis, loss of coolant  
10 accident operational transients and shortcomings in  
11 criticality and reload analysis for cores using high-burnup  
12 fuels.

13 The Staff should describe progress being made in  
14 these areas as well, so we look forward to your briefing  
15 today and I understand that copies of the viewgraphs are  
16 available to the entrances to the room.

17 Mr. Callan, please proceed.

18 MR. CALLAN: Thank you, Chairman. Good morning.  
19 Good morning, Commissioners.

20 The last communication with the Commission on  
21 issues surrounding high-burnup fuel was a memorandum to the  
22 Commission dated November 25th, 1996.

23 Today's briefing will pick up from that November  
24 memorandum and summarize NRC work related to high-burnup  
25 including our plans for the resolution.

1           At the table with me are representatives from all  
2 four major technical offices, since the high-burnup fuel  
3 issues impact activities in all four offices.

4           To my left are Tom King and Ralph Meyer from the  
5 Office of Research. Their presentation summarizes the NRC  
6 research program designed to obtain the relevant data to  
7 assess the behavior of high burnup and MOX fuels.

8           To my right is Gary Holahan, representing the  
9 Office of Nuclear Reactor Regulation. Their presentation  
10 summarizes the U.S. operating experience in NRC regulatory  
11 action.

12           Also to my right is Hal Ornstein, representing the  
13 Office for Analysis and Evaluation of Operational Data. The  
14 AEOD summarizes international operating experience.

15           Also to my right is Carl Paperiello, representing  
16 the Office of NMSS, the Nuclear Materials Safety and  
17 Safeguards Office. Their presentation summarizes emerging  
18 issues relating to fabrication and transportation of fresh  
19 fuel and storage and transportation of spent fuel.

20           The Office of Research has played a prominent role  
21 in preparing this presentation and overall in addressing  
22 some of these issues, so I want to turn this meeting over to  
23 them to introduce the technical presentations and to  
24 summarize the overall status at the end. Tom?

25           MR. KING: Thank you, Joe.

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1           If I could have Slide 2, please.

2           [Slide.]

3           MR. KING: Slide 2 shows the outline of our  
4 presentation this morning. As Joe mentioned, the purpose is  
5 to update the Commission on issues related to high-burnup  
6 fuel performance and the Staff activities to address those  
7 and this is a followup to the November 25th, '96 memorandum.  
8 That memorandum focused on two prominent issues, primarily  
9 the control rod insertion issue and the fuel performance  
10 related to reactivity insertion accidents.

11           However, high-burnup affects a lot more than those  
12 two areas and today we intend to take a more comprehensive  
13 look at the issues and the activities that are underway to  
14 address those issues.

15           Accordingly, that is why we have all four offices  
16 involved, because we are -- it is an integrated activity and  
17 we want to --

18           CHAIRMAN JACKSON: Who is integrating? Who is the  
19 point person? I mean who has the responsibility to ensure  
20 that the activities in fact of the different offices  
21 properly inform each other and are integrated?

22           MR. KING: Well, I think we have been trying to do  
23 that at the division level. Certainly, within Research our  
24 counterpart is Gary Holahan and his people and we work  
25 closely with them --



1 CHAIRMAN JACKSON: No, I understand what you are  
2 telling me but I guess what I am really asking you is is  
3 there a lead individual with respect to the activity so  
4 that, you know, everything informs everything else?

5 I mean I understand that you have been looking at  
6 international, you have been looking at domestic, you look  
7 at specific fuel issues, and I am probably somewhat more  
8 familiar with what you have been doing in the research area,  
9 but a concern is to have some coherence, so is there an  
10 individual identified who has the lead in this?

11 MR. KING: At this point I don't think we have one  
12 individual identified.

13 CHAIRMAN JACKSON: Okay, so it is kind of an  
14 emerging activity?

15 MR. KING: It is an emerging activity. As I said,  
16 we are trying to integrate it at the division level among  
17 the offices.

18 CHAIRMAN JACKSON: Okay.

19 MR. CALLAN: Chairman, we will look at that. That  
20 is both good and an obvious thing that we ought to be  
21 looking at and we'll make a recommendation.

22 MR. MEYER: Could I jump in here and say --

23 CHAIRMAN JACKSON: Sure.

24 MR. MEYER: -- we do have this generic issues  
25 management system.

1           It is identified as a generic issue and I am the  
2   Manager for the generic issues so there is some coherence at  
3   least at the working level right now.

4           CHAIRMAN JACKSON: I understand that. That is a  
5   separate question.

6           MR. KING: Okay.

7           CHAIRMAN JACKSON: But anyway, good, Joe. That  
8   keeps me from having to put it in my closing remarks.

9           MR. KING: Okay. The handout is a fairly thick  
10   package. What we intend to do today is not show every  
11   viewgraph. Some are provided here for information, so we  
12   will be skipping over some and just hitting the highlights.

13          If I could have Slide 3, please.

14          [Slide.]

15          MR. KING: What I want to talk about for the next  
16   few minutes on the next three slides is provide an overview  
17   of the issues and then a little bit of background as to what  
18   led up to these issues.

19          We have broken down the fuel performance issues  
20   into two basic categories, in-reactor and out-of-reactor we  
21   have labelled them. However, qualitatively many of the  
22   issues are the same. For example, cladding integrity is  
23   important in-reactor and out-of-reactor.

24          As you mentioned, Chairman Jackson, high-burnup  
25   fuel represents a trend in the industry to reduce costs of

1 electricity production and it is being done in conjunction  
2 with things like longer operating cycles, reducing storage  
3 costs, and also things like power operating.

4 To achieve improved fuel performance the industry  
5 is pursuing several things. They are looking at new  
6 cladding materials. They are looking at higher enrichments.  
7 They are reducing some of their operating margins and they  
8 are radiating materials for longer periods of time.

9 High-burnup was also leading to certain changes in  
10 certain fuel characteristics. Among these are higher  
11 cladding oxidation which leads to embrittlement of the  
12 cladding, higher fission gas release which leads to higher  
13 pin pressure and higher source term fission gas release  
14 source term component.

15 We are seeing different thermal and physical  
16 characteristics of the fuel, for example, fuel  
17 conductivities changing. We are seeing fuel fragmentation  
18 take place as the burnups get higher. We are seeing a shift  
19 in some of the failure modes of the fuel. We are seeing  
20 certainly the higher radionuclide inventory as decay heat  
21 builds up with higher burnup.

22 These things have led to some unexpected results,  
23 some of which you are aware of -- the failure at low energy  
24 inputs from the French tests and Japanese tests on  
25 reactivity insertion accidents, control rod insertion

1 problems at some plants in the U.S. as well as overseas.

2 We are seeing some different failure modes, as I  
3 mentioned, cladding, brittle cladding failures, and fuel  
4 expulsion in some of the tests, and we are seeing larger  
5 fission gas released from fuel, higher than had been  
6 expected.

7 All of these things indicate that we need to look  
8 at our codes and criteria to update them and evaluate their  
9 current applicability to high burnup and all of these things  
10 also affect a number of areas. They affect normal  
11 operation. They affect anticipated operational occurrences  
12 and design basis events and analysis that we do in the  
13 severe accident area.

14 These things are shown on Slide 3, if I could have  
15 Slide 3, please.

16 [Slide.]

17 MR. KING: Traditionally fuel cladding has been  
18 the first barrier in what we call defense-in-depth and the  
19 criteria we had developed many years ago to deal with fuel  
20 integrity had generally kept the risks from fuel failure low  
21 during normal operation, anticipated operational  
22 occurrences, and design basis events.

23 [Slide.]

24 MR. KING: The criteria, on Slide 4, we have shown  
25 the criteria pictorially. They have been established



1 basically for normal operation and anticipated operational  
2 occurrences. The intent of the criteria are to maintain  
3 cladding integrity and basic -- and allow, provide for safe  
4 shutdown of the reactor and basically they correspond to no  
5 release of fission products to the environment.

6 For postulated accidents, which include reactivity  
7 insertion events, loss of coolant accidents, the criteria  
8 are directed toward maintaining safe shutdown, coolable  
9 geometry and the applicable criteria are the Part 100 dose  
10 guidelines that have to be met during those accidents.

11 For severe accidents we don't have any limits on  
12 fuel integrity but clearly the fuel performance affects the  
13 source term and the core melt progression. That is assumed  
14 in risk assessment.

15 CHAIRMAN JACKSON: Let me ask you this question.  
16 Of the postulated accident conditions that you have on Slide  
17 3, which are the greatest contributors to risk?

18 MR. KING: It's somewhat plant-dependent. In some  
19 cases we see LOCAs as the biggest -- as larger than the  
20 others in contributing to risk. In other cases we see a  
21 contribution from ATWS. Never have I see the rod drop or  
22 rod eject accidents be a prominent contributor to risk.

23 MR. HOLAHAN: And the contributions are not from  
24 the design basis ATWS or LOCA, which is a mitigated event,  
25 but it is the related severe accident.

1           CHAIRMAN JACKSON: Right, severe accident, and  
2 where have we been focusing our attention to this point?

3           MR. KING: Our attention from the experimental  
4 programs that are underway have been on the rod drop and rod  
5 ejection accidents. We are now shifting that focus to LOCAs  
6 and the ATWS.

7           Of the criteria that have been developed and are  
8 currently in place, developed a number of years ago, based  
9 upon data from primarily tests with fresh fuel and fresh  
10 cladding or cladding and fuel that had achieved low burnup.  
11 It had also been based upon zircalloy and zirco cladding,  
12 and with the new cladding that is being developed by the  
13 industry, some of the properties are clearly going to be  
14 different than what has been used in the past to establish  
15 our criteria, so the goal of our work is to continue to  
16 assess our criteria and our codes so that we can assure that  
17 the risk remains low from fuel performance issues.

18           We don't think there is immediate safety concern  
19 in this area for several reasons.

20           One, the accidents remain low probability.

21           Two, it takes time to achieve high-burnup.

22           Three, we think from the data that we have  
23 received to date and the direction we feel the criteria are  
24 going to go, we feel that plants will be able to -- like be  
25 able to meet these criteria once we get the revisions made

1 and get them in place.

2 CHAIRMAN JACKSON: This is kind of a curve ball,  
3 but is it true that there was an observation with MOX fuel  
4 in Europe that at low-burnups then what we consider to be  
5 high-burnups with uranium dioxide based fuel, that there was  
6 some fuel damage for, you know, an energy insertion where we  
7 wouldn't have expected it?

8 MR. KING: Yes, there was a recent test in France,  
9 I believe. Maybe Ralph could --

10 MR. MEYER: Can I take this? This was a test in  
11 the test series in the CABRI reactor in France.

12 The fuel rod did have a fairly high-burnup. It  
13 was 55 gigawatt days per ton. What they have been testing  
14 to in that same test series has been a little higher, up  
15 around 60-63 gigawatt days per ton.

16 I personally thought that the failure that  
17 occurred in this test was totally expected. It failed  
18 around 110 or 120 calories per gram during a reactivity  
19 transfer, which is exactly where I think the rest of the  
20 data are telling us the failure should occur.

21 What did happen was that there was a larger  
22 pressure pulse generated in this test than in other tests  
23 but it had a total energy deposition that was higher than  
24 the other tests they had performed so there is some concern  
25 that the microstructural changes in the pellet due to having

1 more plutonium in there may lead to additional fragmentation  
2 and some increase in this fuel-coolant interaction that  
3 leads to the pressure pulses, but at this point I think that  
4 remains to be seen.

5 I thought it was a pretty normal test but I know  
6 even the people that performed it were a little surprised at  
7 the energetics of it.

8 CHAIRMAN JACKSON: Thank you.

9 MR. HOLAHAN: I think what all of this experience  
10 has at least taught me is it's really the condition of the  
11 clad before the test or before an accident that's the  
12 primary driver of whether it fails or doesn't fail during  
13 the test. And then I think there are other contributing  
14 considerations like where the energy is being generated in  
15 the fuel pellet and the fact that MOX fuel has a little bit  
16 different reactivity characteristics. I think largely what  
17 we're seeing here, the low-energy failures are because of  
18 the condition of the cladding. That's the primary issue.

19 CHAIRMAN JACKSON: Okay.

20 COMMISSIONER McGAFFIGAN: Could I ask just in a  
21 clarification, when you use numbers like 6 -- 60 gigawatt  
22 days per metric ton, is that batch average, peak, rod,  
23 what -- just so you all stay on the same language all  
24 through the briefing.

25 MR. MEYER: When we talk about an individual test,



1 it's the actual burnup in the test section that's being  
2 tested. These test sections are a little over a foot long,  
3 and they come from locations in the rod where the burnup  
4 profile is pretty uniform. So when we talk about a specific  
5 test it will be for the fuel in that test. It's fairly  
6 constant. You'll see that requirements are often quoted in  
7 different units, and it makes a pretty big difference. The  
8 French, for example, talk about their limit at 47 gigawatt-  
9 days per ton. This is an assembly average number, whereas  
10 we talk about our limit at 60 gigawatt-days per ton, and  
11 that's the average for the peak rod. There's about a 10-  
12 percent difference in the unit.

13 CHAIRMAN JACKSON: Okay. Tom.

14 [Slide.]

15 MR. KING: Okay. Slide 5 summarizes the out-of-  
16 reactor fuel issues, and as I said earlier, qualitatively  
17 many of these are the same as the in-reactor issues.

18 Cladding integrity is important in the outer  
19 reactor area, the higher decay heat, you'll need the higher  
20 cladding temperatures, clearly the higher oxidation that  
21 occurs in the reactor is an important consideration out of  
22 reactor.

23 The higher pin pressure that occurs due to higher  
24 burnup is a consideration in any out-of-reactor issues.

25 The source term is another common issue due to the

1 higher radionuclide inventory, the potential for fuel  
2 dispersal upon cladding rupture, shielding issues.

3 Criticality is an issue, both in the fabrication  
4 and the transportation and storage side.

5 So even though qualitatively many of the issues  
6 are similar, when you get out of reactor you're also talking  
7 about differences in time scales at which you're looking at  
8 the performance of the fuel as well as the descriptions of  
9 the types of accidents that need to be considered.

10 If we could go on now to --

11 COMMISSIONER ROGERS: When you say something's an  
12 issue, what do you really mean by that? Do you mean that  
13 it's something that we don't have adequate data on or  
14 adequate data don't exist, or it's just something that has  
15 to be carefully included as one moves into higher  
16 enrichments but that basically what needs to be known is  
17 already known?

18 MR. KING: It could be some of both. Basically  
19 when we identify things as issues in the beginning, they are  
20 areas that we feel are affected by higher burnup that we  
21 need to look into. In some cases we find there are data,  
22 sufficient data to upgrade a code or revise criteria. In  
23 other cases we find out there aren't and we need to figure  
24 out a plan or a strategy to get that data.

25 COMMISSIONER ROGERS: Well, I wonder -- excuse me.

1 CHAIRMAN JACKSON: That's all right.

2 COMMISSIONER ROGERS: During your presentation at  
3 some point before we all go home whether you couldn't touch  
4 upon those issues where really additional data or research  
5 are needed that just simply doesn't exist.

6 MR. KING: Yes. We're going to cover that as we  
7 get to the -- Ralph covers the research program, Gary covers  
8 the NRR activities, and Carl the NMSS activities. So we'll  
9 cover that.

10 COMMISSIONER ROGERS: Right.

11 MR. KING: We can go to slide 7.

12 [Slide.]

13 MR. KING: Slide 7, you know, in a box diagram  
14 shows the major components of the fuel research program that  
15 exists today. It's broken out into three main areas that  
16 deal with reassessing the criteria, updating the codes, and  
17 getting experimental input to support these activities.

18 We also have another activity in the criticality  
19 area looking at extending the criticality codes that are  
20 used for fuel fabrication to higher enrichments.

21 And then up in the upper left-hand corner of the  
22 slide I have a little item called mixed oxide fuel white  
23 paper. That's an initiative we're undertaking in house in  
24 research to do some homework in case we get involved in  
25 reviewing applications for mixed oxide fuel, and basically

1 it's to look at what do we know from past work, what do we  
2 know from what's going on overseas, and what are the issues  
3 that we need to deal with if we get into a mixed oxide  
4 review.

5 That's all we're really going to say about mixed  
6 oxide. The rest of the presentation is going to concentrate  
7 on the activities under way dealing with the operating  
8 reactors today, and I'm going to turn it over to Ralph to  
9 talk about --

10 CHAIRMAN JACKSON: Before you do that, if you look  
11 at these boxes on page 7, does that cover the full scope of  
12 issues that --

13 MR. KING: That research is looking at; yes.

14 CHAIRMAN JACKSON: Right. No, not that you're  
15 looking at, but that have been identified.

16 MR. KING: I think the one area that we're looking  
17 at that's really not in the research program --

18 CHAIRMAN JACKSON: Okay.

19 MR. KING: Is the difficulty with incomplete  
20 insertion of control rods, and we're dealing with that  
21 through operating experience with the vendors, not really  
22 through a research program.

23 CHAIRMAN JACKSON: Okay, so you're going to talk  
24 about that.

25 MR. KING: Yes.



1 CHAIRMAN JACKSON: Okay.

2 MR. KING: I think there may be some things that  
3 come out of NMSS that may expand the scope of research  
4 activities as well, and we'll talk about that.

5 CHAIRMAN JACKSON: Okay. Thanks.

6 MR. KING: Ralph will now describe the research  
7 program.

8 MR. MEYER: Let's stay with slide 7 for just a  
9 minute, because these are the main elements of the program,  
10 and let me just touch on each of these before going on.

11 First of all, look at the center box at the bottom  
12 of the page where it talks about updating our analysis  
13 tools. We actually started this work before we had results  
14 from CABRI or the control rod sticking problem came up, so  
15 we had begun to modify the codes, and I'll give you some  
16 additional details on the code work on a later slide.

17 CHAIRMAN JACKSON: You are going to address the  
18 question of whether NRC codes can adequately predict fuel  
19 and clad behavior at the burnups now being used by --

20 MR. MEYER: Yes, I can do that. I can do that  
21 right now and say that the three codes that the NRC uses  
22 that specifically deal with fuel behavior are the three  
23 listed here. The first one is a steady-state fuel behavior  
24 code. FRAPCON is an evolution of an older code, GAPCON,  
25 that many people have used.

1           This code and its predecessor are used routinely  
2   in licensing reviews because one of the main outcomes of  
3   these reviews depends critically on something you calculate  
4   here, that is, the loss-of-coolant accident analysis, the  
5   ECCS behavior is very strongly dependent on the stored  
6   energy that's in the fuel rod at the beginning of that  
7   accident. That's calculated in detail with this code, each  
8   of the vendors has a reviewed corresponding code, and this  
9   code is used as an audit tool to check their work.

10           This code has been updated to handle burnups up to  
11   at least 65 gigawatt-days per ton. That work has recently  
12   completed -- the final peer-review meeting on that code is  
13   next week, and the release of the code will follow as soon  
14   after that as we can respond to any things that come up in  
15   the meeting next week.

16           The transient code is not used routinely in  
17   licensing but it's used from time to time for special  
18   studies, and also particularly for analyzing experimental  
19   results. We are just under way in making revisions to that  
20   code. We kind of have to do these one after another because  
21   it is the same contractor and we don't have many people  
22   working in this area these days. So that work is under way  
23   and will take a year or so. But we're still able to use the  
24   code during this time if we know exactly where its  
25   deficiencies are and can keep an eye on them.

1           The RAMONA code, transient neutronics code, has  
2    been used for our high-burnup calculations, and it does have  
3    some significant uncertainties associated with high-burnup  
4    applications, and we have looked into those uncertainties.  
5    We have not made any adjustments yet to the code for that.

6           CHAIRMAN JACKSON: So that's the third in a row?  
7    You said you had one contractor.

8           MR. KING: No, I'm sorry. You can't read my mind.

9           No, we actually have two contractors. We have one  
10   for the thermal mechanical fuel behavior codes, and a  
11   different one for the neutronics code. That work has been  
12   going on simultaneously.

13          CHAIRMAN JACKSON: Okay.

14          MR. KING: Okay. So at about the same time we  
15   started the code work, this was about 4 years ago, we also  
16   started looking at the acceptance criteria that we use in  
17   regulatory work that related to fuel behavior. I think of  
18   these as speed limits that are related to fuel behavior.  
19   And we'll talk more about those as well.

20          So that's sort of assessment work, and then we  
21   have some experimental programs. Now most of our  
22   experimental work at this time is brought in from overseas.  
23   All of the work on the reactivity accidents, the recent  
24   work, was done overseas. Of course we have a tremendous  
25   amount of work in our historical existence on this in the

1 old Spartan PBF reactors. And we have in fact gone back and  
2 looked at those data as well.

3 But as you saw earlier in the discussion, the  
4 loss-of-coolant accident in our view is at least as  
5 important, probably more important, than the reactivity  
6 accident from a risk point of view, and so we decided that  
7 there was not enough work, experimental work, being done on  
8 the loss-of-coolant accidents, and is something where we  
9 still have the expertise in the U.S. and where we can get in  
10 the game and actually do some experimental work. So we have  
11 initiated a program. I'll talk about that briefly on a  
12 later slide.

13 The Halden program in Norway is providing sort of  
14 baseline thermal properties for the computer code  
15 development, and we utilize those data.

16 Finally then on the mixed oxides, what we plan is  
17 in the near future to do a sort of review, a white paper, on  
18 the effect of the mixed oxides on all of the same things  
19 that we're looking at at high burnup. These will be I  
20 expect modest effects rather than huge effects.

21 MR. HOLAHAN: If I could go back to your earlier  
22 question, Dr. Jackson, I think it's fair to say that the  
23 experimental data is in some sense used in developing or  
24 verifying at least the first two codes, because the steady-  
25 state analysis can be compared with Halden, and the



1 transients analysis can be compared with the tests. The 3-D  
2 neutronics really don't have, you know, an experimental  
3 facility to be compared to, but there are code-to-code  
4 comparisons that are done to give you some comfort in the  
5 capability of that code.

6 MR. MEYER: Okay, slide 8.

7 [Slide.]

8 MR. MEYER: Well, the objective in a word is to  
9 maintain the technical expertise here that we need, and I'm  
10 not going to dwell on any of this, but you'll see that in  
11 doing this that our work is focused on the in-reactor  
12 issues, and here we have made a distinction in the past.  
13 We've talked about technical issues versus regulatory  
14 issues, and -- but we've focused our work on the technical  
15 issues where questions arise that might have a regulatory  
16 impact is where we have turned the spotlight, and we've done  
17 this by trying to keep our codes up to date, getting data  
18 from other programs, as I mentioned, we have a lot of  
19 involvement with the international programs, and we also  
20 have some recent initiatives with industry groups and DOE to  
21 try and get some cooperation going. We'll mention more of  
22 that in just a minute.

23 CHAIRMAN JACKSON: Let me make sure I understand.  
24 What NRC regulatory criteria, you know, fuel --

25 MR. MEYER: Okay.

1 CHAIRMAN JACKSON: Or burnup damage limits might  
2 be affected by --

3 MR. MEYER: Okay. If you think about that pyramid  
4 from slide 4 or 5, whatever it was, for each of the design-  
5 basis accidents, and there's just a handful of design-  
6 basis accidents that we use in licensing, the most prominent  
7 of those is the loss-of-coolant accident. So let me talk  
8 about the loss-of-coolant accident for a minute.

9 The main speed limit or regulatory criterion in  
10 the loss-of-coolant accident is that after you go through  
11 this big transient that you maintain the coolable geometry  
12 of the core. And you do this by demonstrating in an  
13 analysis that the peak cladding temperature remains below  
14 2,200 degrees Fahrenheit and that the oxidation that occurs  
15 during that transient remains below 17 percent of the wall  
16 thickness being oxidized. That's the way it's laid out in  
17 10 CFR 50.46.

18 Then you have models that you have to use to  
19 calculate those things, and those models involve the  
20 oxidation kinetics, the occurrence of rupture of the  
21 cladding, the amount of strain, how big does the balloon  
22 grow, and how much blockage does this cause in the core.  
23 All of these things are affected by the ductility of the  
24 material and its mechanical properties, which are in turn  
25 affected by the fluents and the oxidation that it gets as it

1 goes to higher and higher burnups.

2 And all of the testing that was done to establish  
3 the 2,200 number, the 17-percent number, the Baker-Just  
4 oxidation kinetics that have been used extensively, and the  
5 models that are embedded and improved and stamped and locked  
6 in the vault for these codes were all based on tests with  
7 fresh fuel rods back in the seventies.

8 CHAIRMAN JACKSON: Okay.

9 MR. KING: For example, the concern is you get a  
10 lot of oxidation as you proceed to higher and higher  
11 burnups. That tends to eat into the 17-percent criteria  
12 that's in the regulations. The cladding becomes embrittled.  
13 You don't get the balloon and rupture type failures anymore  
14 with the brittle cladding. So we're looking into what kind  
15 of failures are we going to get and do we need to change our  
16 criteria or not.

17 MR. MEYER: Now, there are also criteria for the  
18 rod drop -- rod ejection accident, there are a whole bunch  
19 of criteria for the normal operating regime, 1-percent  
20 cladding strain, fuel rod pressures versus the system  
21 pressure, lots of little things, but the big one gives -- I  
22 think characterizes the situation.

23 MR. HOLAHAN: There's one additional difference,  
24 and that is for the LOCA the criteria and the methods of  
25 analysis are pretty much in the regulations. In most of the

1 other areas the regulations call for some requirement, but  
2 in most cases they don't specify what the criteria ought to  
3 be or how to do the calculation. And so there's either a  
4 regulatory guide or a case-by-case review to establish  
5 those.

6 CHAIRMAN JACKSON: Commissioner McGaffigan.

7 COMMISSIONER MCGAFFIGAN: Could I ask how high are  
8 we prepared -- is our research program aimed at looking at  
9 burnups? The DOE program that may or may not be funded by  
10 Congress says one of its goals and objectives of the spent-  
11 fuel minimization R&D program is to reduce the amount of  
12 spent fuel generated in nuclear powerplants. The principal  
13 areas of research include resolving technical issues with  
14 current high burnup fuel at 60 gigawatt-days per metric ton,  
15 developing fuel performances supporting 100 gigawatt-days  
16 per metric ton burnups, and analyzing, et cetera.

17 Do we have anything in our codes or our research  
18 experience that if DOE were to pursue that program we'd be  
19 able to be comfortable with 100 gigawatt-days per metric  
20 ton? I assume that's peak rod burnups.

21 MR. MEYER: We are familiar with the DOE proposal  
22 and the degree of cooperation that would exist would provide  
23 us with the basis for making the adjustments that we need to  
24 make, but we are not at this time moving toward 100  
25 gigawatt-days per ton. We are operating with peak rods in

1 the neighborhood of 60 to 62 gigawatt-days per ton. There's  
2 probably a need for a little elbow room there, maybe, I  
3 don't know, 65 or 70, and I think when you see the  
4 underlying phenomena that take place as you accumulate  
5 burnup that you can develop the ability to extrapolate a  
6 little bit.

7 I mean, what we see is the breakaway oxidation  
8 phenomenon that occurs around 40 to 50 gigawatt-days per  
9 ton, and this is the culprit. This is why the earlier  
10 requirements which were based on data out to around 40  
11 gigawatt-days per ton didn't just work at higher burnups  
12 because something happened. We know what happened now, and  
13 of course there would be the question if you get up to 100,  
14 is something else going to happen, and you would indeed need  
15 a data base, but if, you know, if DOE goes forward with that  
16 program, the program itself is to generate that data base.

17 COMMISSIONER McGAFFIGAN: But that would also as I  
18 understand it -- what the goal, since this is called waste  
19 minimization, would be to be able to keep for three  
20 cycles -- three 2-year cycles -- the rods in, you know, a  
21 fresh rod being able to stay in for three 2-year cycles in a  
22 reactor rather than two, which is typical I guess today, and  
23 to do that they'd have to go to 7 percent enrichment, as I  
24 understand it, if they were going to get all the way to  
25 that, how far are you extrapolating or how much -- if they

1 pursue that program, I guess I'm basically asking what do we  
2 have to do and what costs are there going to be for us to  
3 sort of stay abreast of it and be ready to act on it should  
4 somebody come in and ask us to act on it?

5 MR. KING: We haven't sketched out the costs that  
6 would be associated with trying to respond to the DOE  
7 program. We currently have steady-state irradiation data  
8 out to the low seventies in terms of burnup, and we have  
9 transient data particularly for the RIA's out to the mid-  
10 fifties, low sixties. If DOE is going to go up to something  
11 like 100, we currently don't have the data, and we have --

12 CHAIRMAN JACKSON: Is it also based on enrichments  
13 of 5 percent or less?

14 MR. KING: Yes. The French and the Japanese tests  
15 are based on enrichments of 5 percent or less. The Halden  
16 steady-state data that goes up to the low seventies I'd have  
17 to check, but if it's greater than 5 percent, it's probably  
18 not much greater.

19 COMMISSIONER McGAFFIGAN: Is there anyone else in  
20 France, which is a leader in I guess this area, or at  
21 least -- or Japan or whatever -- who's looking at trying to  
22 get to these sorts of waste-minimization goals. This partly  
23 comes up, Madame Chairman, because, you know, in this  
24 convention on waste that's being negotiated at the moment,  
25 this notion of waste minimization is in there, and we don't

1 have much of a -- it's not really in our regulatory  
2 framework, and I'm trying to understand whether, you know,  
3 there's going to be impetus as a result of this waste  
4 convention should it be negotiated for us to do something  
5 like this to meet a waste-minimization objective of some  
6 sort.

7 MR. KING: I don't know of any overseas program  
8 that's trying to -- has the goals of the DOE waste-  
9 minimization program.

10 CHAIRMAN JACKSON: The same countries that we  
11 might look to to get the data also happen to be ones that  
12 reprocess, and that's also part of their waste-minimization  
13 strategy.

14 MR. KING: When we get to the last slide on  
15 concerns you'll see one of our major concerns is the impact  
16 of this DOE waste-minimization program on --

17 COMMISSIONER McGAFFIGAN: Okay. I'm sorry to have  
18 jumped the gun.

19 CHAIRMAN JACKSON: No, no, no; that's a good  
20 question.

21 MR. HOLAHAN: I think it's also fair to say that  
22 our experience to date has taught us that what we should be  
23 doing if increasing burnups at all is to be doing it in  
24 measured steps, and long before we thought about anything  
25 like a hundred, I think we need to think about 65.

1           CHAIRMAN JACKSON: Why don't we let you get  
2 through a few more viewgraphs, because I think we always  
3 seem to preempt what you may have had in mind.

4           [Slide.]

5           MR. MEYER: Okay. Well, look at slide 9, and I  
6 think that we already talked about almost everything on this  
7 page as a result of some of the early questions, so we can  
8 move on, and we're skipping 10 and 11, so that moves us  
9 right to the schedule.

10           A few comments about the reactivity-initiated  
11 accidents. These programs that we've been talking about in  
12 France and in Japan are in my opinion at a point now where  
13 we're on a plateau of understanding, and it's going to be 3  
14 to 5 years before they're able to reset these programs,  
15 revise their hardware, and get improved data. So we did an  
16 interim assessment of all of the data, and in fact issued a  
17 research information letter summarizing these data and  
18 suggesting some revised criteria for this accident. That  
19 was issued just on the 3rd of this month.

20           New test results are hoped for from both programs  
21 in France and Japan. In France in particular I'm sure  
22 you've heard talk of this water loop that they're hoping to  
23 construct and do tests in that would be much more typical  
24 than the current liquid sodium loop. So, you know, in about  
25 5 years I expect that we would have a significantly improved



1 data base and can go back and revisit that. But I think  
2 we've provided a technical basis for an interim position  
3 should we decide that such an interim position is warranted.

4 Loss-of-coolant accidents, our work is under way.  
5 We are working with EPRI and DOE. They intend to help us  
6 identify and acquire specimens of fuel rods burned to high  
7 burnup in commercial U.S. power reactors, and will share  
8 some of the costs of acquisition of the specimens and the  
9 shipping and initial preparation, but then of course we'll  
10 run our own program when we get them up to the hot cells.

11 That work will include both loss-of-coolant  
12 simulation tests and also some general mechanical properties  
13 testing over a range of transient conditions that should  
14 be -- that we intend to be applicable both to the loss-of-  
15 coolant-type transients, the reactivity-type transients,  
16 everything in the range of the accidents and transients that  
17 we have to look at in our safety analysis.

18 Also anytime you work with irradiated fuel rods  
19 it's kind of slow going, so this is a 3- to 5-year program  
20 to get significant results as well.

21 The anticipated transients without scram, the  
22 ATWS, there's one ATWS, the BWR power oscillation, that  
23 we're going to look at analytically. At first we're just  
24 going to try and size it up. It does have some rather large  
25 power oscillations. The timing of those is quite different

1     than the timing in the pulse of a rod-drop or rod-ejection  
2     accident. So at this point it's not clear whether the data  
3     that have come from these pulse tests can be applied to the  
4     power oscillations, and that's what we're going to try and  
5     shed some light on with some calculations that we can do in  
6     the near future, and we're going to do that.

7             CHAIRMAN JACKSON: No experimental program?

8             MR. MEYER: Nothing planned.

9             MR. HOLAHAN: We are also and over the last few  
10    years have been working with the BWR owners' group on their  
11    emergency operating procedures to minimize the likelihood  
12    that unstable oscillations would occur during an ATWS, so  
13    we're looking at prevention at the same time that we're  
14    looking at the potential consequences of power spikes if  
15    they would occur.

16            MR. MEYER: And finally the source term is this  
17    fall we're going to begin looking carefully at source-term  
18    issues. There will be some small changes in gap inventory,  
19    the fuel particulate size will be different, there's some  
20    shift in the isotopics, but in general I would characterize  
21    our expectation as a small step change in going from the new  
22    NUREG 1465 source term to one that accounts for a high  
23    burnup compared to the big step that was taken between the  
24    old TID source term and the 1465.

25            CHAIRMAN JACKSON: But at this point the new

1 source term does exclude high burnup fuel?

2 MR. MEYER: That's correct.

3 Okay, Gary Holahan from NRR is now going to talk  
4 about the NRR activities on high burnup fuel.

5 MR. HOLAHAN: Slide 14, please.

6 [Slide.]

7 MR. HOLAHAN: The general industry trends have  
8 already been mentioned by Tom in his opening remarks. I  
9 don't think I need to go over those again.

10 CHAIRMAN JACKSON: Let me ask you one quick  
11 question.

12 Are we able to adequately audit industry core  
13 reload analysis for high-burnup fuels and how do we ensure  
14 that safety margins are maintained with different fuel  
15 designs and changes to fuel designs at high-burnup  
16 conditions?

17 MR. HOLAHAN: We really have a program that has a  
18 number of pieces to it. One is that when a new fuel design  
19 is proposed, usually from the vendor is some sort of topical  
20 report, the Staff does review and approve that and looks at  
21 many of these issues -- cladding stresses, the effect of  
22 increased burnup, lead test assembly program to demonstrate  
23 what is included in the analysis.

24 In addition, the Staff will review and approve  
25 individual reload analyses where there are changes in the

1 technical specifications so at that point we would review  
2 changes in fuel design or changes in methodologies and we  
3 would review the codes involved at that point.

4 What we have really been stressing in recent years  
5 is a shift from that sort of review and approval mode into  
6 more of an inspection type activity and so over the last few  
7 years we have inspected all of the fuel vendors. I think  
8 over the last approximately two years we have done about  
9 nine major inspections at GE, Westinghouse, ABB, CE,  
10 Siemens, and we have also --

11 CHAIRMAN JACKSON: Now how does that track to  
12 actually dealing with the industry core reload analysis?

13 MR. HOLAHAN: In many cases -- reloads are really  
14 done in two ways.

15 Some licensees do their own analysis. Many of  
16 them rely upon --

17 CHAIRMAN JACKSON: The vendors?

18 MR. HOLAHAN: -- the fuel vendor to do the  
19 analysis, so as part of our inspection of the fuel vendor  
20 activities we not only look at, for example next week we are  
21 looking at Siemens and their fuel manufacturing activities,  
22 but last week at Siemens we were looking at their codes and  
23 thermal hydraulic analysis.

24 So we look at --

25 CHAIRMAN JACKSON: We look at the adequacy of the

1 codes.

2 MR. HOLAHAN: Yes.

3 CHAIRMAN JACKSON: We look at how much they are  
4 extrapolating beyond existing data.

5 MR. HOLAHAN: On an audit basis, yes. Now  
6 recognizing that for example we may only spend one week with  
7 a few experts to go and look at a code, so we can't cover  
8 100 percent of what is in those codes but we do try to  
9 select those areas that seem to be significant.

10 We use not only experienced inspectors and QA  
11 qualified inspectors but we also use our own thermal  
12 hydraulic experts -- the people in this building who are  
13 actually capable of running loss of coolant accident or  
14 RAMONA type calculations. Those people are actually out  
15 looking at the vendors' comparable analyses from a very  
16 technical point of view.

17 CHAIRMAN JACKSON: Okay, but I guess what I am  
18 really trying to get at is this, you know, when I was  
19 listening to Mr. King here, I guess I am trying to get at  
20 the issue of the adequacy of the codes as opposed to what  
21 they do -- that is, are we really looking at the adequacy of  
22 the codes or the regions of concern with respect to high-  
23 burnup?

24 MR. HOLAHAN: Well, I have to say we do it  
25 selectively.

1           We look at various codes in different ways. It's  
2       probably fair to say that LOCA analysis gets more attention  
3       than other areas, and so for example we do things like in  
4       both our review and inspection activities we ask the  
5       manufacturer, the Applicant, to compare those calculations  
6       to LOFT experiments, for example.

7           So we do look for verification type activities  
8       where it is possible.

9           Now there are not that many opportunities for  
10      saying show me how your code can be demonstrated to be  
11      useful at high-burnup, okay?

12           CHAIRMAN JACKSON: Right.

13           MR. HOLAHAN: I think as mentioned earlier we are  
14      just beginning to do some experimental work to show how  
15      high-burnup might affect the fuel rod performance for LOCA  
16      activities, so the mode we tend to be in is in our review  
17      and inspection activities we are dealing with sort of the  
18      current state-of-the-art understanding.

19           Meanwhile, we are sort of pushing the state-of-  
20      the-art with the research program, and then when we find  
21      things that are new and different, we will go back to the  
22      industry and say this looks like a legitimate issue that  
23      needs attention -- what are you doing about this?

24           CHAIRMAN JACKSON: I appreciate what you are  
25      saying, but I guess I am really trying to get at a specific

1 issue, which has to do with on what do we predicate a  
2 regulatory decision with respect to core reload analysis,  
3 and if, you know, what is being presented represents an  
4 extrapolation beyond where there really is data, how does  
5 that drive the regulatory decision?

6 MR. HOLAHAN: Well, I think in the past there have  
7 been examples like that. In fact, you have heard some  
8 examples where the original analyses were maybe based on the  
9 35,000 megawatt days per ton and here we are allowing  
10 licensees to go to 62.

11 In those cases what we are using is the vendor's  
12 engineering analysis and our own judgment plus a lead test  
13 assembly program which is supposed to demonstrate that their  
14 assumptions are actually coming through in the field.

15 Now what we learned is that lead test assembly  
16 programs, because they tend to be conservative -- for  
17 example, we don't allow licensees to put lead test  
18 assemblies which are in fact extrapolations in some way of  
19 beyond what was done before -- we don't allow them to put  
20 those in rodged positions, okay? Well, that is sort of a  
21 prudent safety approach, but what it does is it eliminates  
22 the possibility that you get any information on the  
23 interactions of that design with a control rod in it.

24 So when we saw that there were a number of  
25 difficult issues with burnup, control rod problems, issues

1 with the reactivity tests, we basically told the fuel  
2 vendors more than a year ago that we would not approve any  
3 increases in burnup until a number of these issues had been  
4 settled.

5 I think that is -- the four major items I am going  
6 to cover really are things that need to be better settled  
7 before there are any other increases in burnup, but in the  
8 meantime we are in the position where there are some  
9 extrapolations from the scientific database to what is being  
10 allowed in the field.

11 We are continuing to watch operating experience  
12 and test data to make judgments about the safety of those  
13 conditions.

14 CHAIRMAN JACKSON: Okay.

15 COMMISSIONER McGAFFIGAN: Were you expecting to  
16 get applications for increases in burnup before that  
17 analysis was made?

18 MR. HOLAHAN: Yes.

19 COMMISSIONER McGAFFIGAN: How high were they  
20 likely to be asking you to go?

21 MR. HOLAHAN: Well, I don't know of any specific  
22 examples but from general discussions of what the industry  
23 is interested in, I think it would be fair to say that  
24 65,000 megawatt days per ton and probably 70-72,000 megawatt  
25 days per ton are things that are not too far off and to a



1 certain extent we have slowed down the industry's move to  
2 those levels.

3 COMMISSIONER McGAFFIGAN: Was the intent to use  
4 that fuel in this country or to use it for export to -- how  
5 are other regulatory bodies dealing with this issue?

6 MR. HOLAHAN: I am not so familiar with the market  
7 for fuel in other countries. I think at levels of 65,000-  
8 70,000 megawatt days per ton that would be useful to U.S.  
9 utilities in planning for a two-year cycle.

10 It would give, not that it is absolutely  
11 necessary, but that it would give them additional  
12 flexibility on how to design those reloads and it would  
13 probably allow them to use some of the fuel more fully than  
14 they currently can.

15 COMMISSIONER McGAFFIGAN: So at that level if they  
16 want to run for two two-year cycles they could keep the fuel  
17 in, fresh fuel rod could expect to last two two-year cycles  
18 at that point?

19 MR. HOLAHAN: I think so, yes.

20 MR. KING: From industry papers I have read, the  
21 numbers Gary has quoted are about what the industry is  
22 targeting to achieve.

23 Overseas, France and Japan and others have set  
24 burnup limits and utilities are trying to increase those for  
25 economic reasons also and I think the numbers they are

1 shooting for are comparable to what the U.S. industry is  
2 shooting for.

3 CHAIRMAN JACKSON: Do we have actual energy  
4 deposition criteria that we use and does any of the foreign  
5 data suggest that, you know, the energy deposition criteria  
6 are violated at elevated fuel performance?

7 MR. HOLAHAN: Yes. I will address that directly.

8 CHAIRMAN JACKSON: Okay.

9 [Slide.]

10 MR. HOLAHAN: If I could have Slide 15 you will  
11 see it is the first bullet on Slide 15. This is just a  
12 summary of the four issues that I am going to cover -- clad  
13 integrity during reactivity accidents is in fact exactly the  
14 area where energy deposition tests is showing something  
15 inconsistent with what is in our regulatory standard.

16 I also talk about the general aspects of fuel  
17 performance with increased burnup, related topic of  
18 oxidation buildup, or cladding oxidation during normal  
19 operation and what we think needs to be done in that area,  
20 and our ongoing dealing with the incomplete rod insertion.

21 I think we can skip 16 and go directly to the  
22 technical issues, starting with 17.

23 CHAIRMAN JACKSON: Are you going to talk about  
24 current licensing basis criteria? Are you going to come  
25 back and talk about that?

1 MR. HOLAHAN: I am going to talk about it in the  
2 context of each of these technical issues.

3 CHAIRMAN JACKSON: Okay. All right, and you are  
4 going to talk about how -- what criteria you think need to  
5 be revised?

6 MR. HOLAHAN: Yes.

7 CHAIRMAN JACKSON: Okay.

8 [Slide.]

9 MR. HOLAHAN: On Slide 17 the one -- this is the  
10 one that we know needs to be revised, and that is cladding  
11 integrity during reactivity accidents, rod ejection for the  
12 PWRs or rod dropout for the boiling water reactors.

13 I think Tom mentioned it in his introductory  
14 remarks. We don't consider this a significant safety issue  
15 because of the low probability of the event and limited  
16 consequences but we have seen in the data that our criteria  
17 are not sufficient to prevent damage of the fuel and so what  
18 we would like is to have good regulations based on good  
19 scientific evidence, and what we have got now is new  
20 information that shows that the criteria that are in our  
21 regulatory guidance and have been used to license many of  
22 these reactors are inconsistent with the experiments.

23 So we have a situation where we feel that those  
24 criteria need to be revised. Now what we see is the  
25 criteria need to be revised downward from something like 170

1 calories per gram, recommended value, interim value from the  
2 Office of Research is 100 calories per gram. They have  
3 recently sent NRR a letter with that and a few other  
4 recommendations. We are in the process of dealing with  
5 that.

6 We have been working pretty closely with them over  
7 the last few years and the 100 calories per gram does seem  
8 like a sensible interim limit.

9 CHAIRMAN JACKSON: Now you say it is not a  
10 significant safety issue because of its low probability and  
11 limited consequence, so what kind of timeline are you  
12 operating on in terms of considering this recommendation  
13 from Research?

14 MR. HOLAHAN: I think there are a couple of  
15 aspects to it.

16 The recommendation relating directly to the  
17 criteria, interim 100 calories per gram, we could be able to  
18 make that decision relatively quickly.

19 There are some related recommendations with  
20 respect to things like inspection of the fuel and I think we  
21 need to work through that and think about the implications  
22 of what kind of inspection. I think we don't know quite so  
23 much about the implications on the operation of the reactor  
24 system and what constitutes an effective inspection program  
25 and how would it impact operation of the plant and so forth,

1 so we need to sort some of that out before we make a  
2 recommendation.

3 COMMISSIONER MCGAFFIGAN: Could I ask --

4 CHAIRMAN JACKSON: Please.

5 COMMISSIONER MCGAFFIGAN: What is the effect of  
6 going to 100 calories per gram on licensees, either fuel  
7 cycle or utilities? Is there fuel out there at the moment  
8 that will -- or configurations that will be affected?

9 MR. HOLAHAN: We don't think so.

10 That goes really to the fourth bullet, which is  
11 where do get the analysis that shows that the revised  
12 criteria are being met?

13 The industry has through its owners group done  
14 some what I would call generic calculations which show that  
15 typically both BWRs and PWRs are well below 100 calories per  
16 gram for rod ejection or rod dropout, and that is because  
17 they have gone to a more sophisticated analysis -- 3D  
18 neutronics calculations.

19 In addition, it reflects the fact that in PWRs for  
20 example the reactors are not run with rods in the highly  
21 inserted positions as the reactors were originally designed  
22 maybe two decades ago.

23 For improved fuel performance they are basically  
24 run in unrodded configurations and so there is nothing to  
25 eject really at full power and at intermediate powers it

1 is -- the reactivity worth available for ejection is really  
2 lower than it was assumed in the mid-'70s when most of these  
3 original calculations were done.

4 We are now in the position where we have some  
5 generic calculations which say our revised criteria can be  
6 met. The Staff is in the position to do some calculations  
7 to say it is reasonably comfortable with it. But we have to  
8 make a decision about whether from a regulatory point of  
9 view whether that is sufficient because what we have got on  
10 the licensee's docket is a very conservative analysis  
11 against a non-conservative criteria.

12 I think that makes frankly for a sloppy regulation  
13 and what we would like is through some mechanism to have the  
14 licensees, hopefully through some generic calculation so  
15 that they don't have to expend excessive resources on what  
16 we have already said is a relatively low safety significant  
17 issue, but I think it needs to somehow find its way into the  
18 FSARs and into the regulatory scheme to get appropriate  
19 analysis to show that the interim criteria are met.

20 I think at this stage we need to sort out what is  
21 the best regulatory approach to doing that so technically I  
22 think the plants can meet the 100 calories per gram criteria  
23 but they just haven't done the analysis to show it -- so we  
24 need to find a way to get from here to there.

25 That is also one of the things we are following up

1 on.

2 CHAIRMAN JACKSON: In rod insertion or ejection  
3 events, the main ones would lead to concerns with energy  
4 deposition?

5 MR. HOLAHAN: Those are the ones that have the  
6 potential for getting close to 100 calories per gram. I  
7 don't think there are any others.

8 I suspect very much that when the ATWS analyses  
9 are done because of the shape, broadened shape, of the power  
10 pulses there is more time available for the energy to  
11 disperse into the coolant, and so I suspect that -- I would  
12 say I am pretty confident that we are dealing with  
13 delimiting cases here with the rod ejection and rod dropout.

14 COMMISSIONER ROGERS: What about power  
15 oscillations?

16 MR. HOLAHAN: I think the BWR stability issues,  
17 low flow or natural circulation, I think those are very  
18 similar to what we are seeing in some of the ATWS  
19 calculations and I think the power spikes can get very high,  
20 but they don't tend to be -- the energy deposition is not as  
21 limited in time as the rod dropout or rod ejection.

22 In addition, we have taken a number of interim  
23 steps over the last several years so that we don't expect  
24 to see the boilers having these problems. They have got  
25 operating administrative controls in place and they are also

1 putting final solutions to these problems in place, for  
2 example, reactor scram on the early oscillations to prevent  
3 the larger examples.

4 So I think we do have delimiting cases here.

5 CHAIRMAN JACKSON: Might this change with MOX  
6 fuel?

7 MR. HOLAHAN: I think probably there are a number  
8 of issues with MOX fuel. The one that I am going to  
9 speculate about, since we haven't studied it too well, we  
10 know that the MOX fuel is more reactive in the sense that it  
11 is -- because of the lifetimes and the prompt criticality  
12 that you can get more energetic spikes, so I think that will  
13 be an issue.

14 I think -- can you get greater than 100 calories  
15 per gram spike with MOX fuel? I don't know but I think  
16 there is more potential there than in the current uranium  
17 fuel.

18 MR. KING: Yes, I would agree with that. I think  
19 it is the neutron, the physics characteristics that really  
20 need to be looked at carefully with MOX fuel.

21 CHAIRMAN JACKSON: Okay, thank you.

22 MR. HOLAHAN: If I can go on to Slide 18.

23 [Slide.]

24 MR. HOLAHAN: In terms of fuel performance, we are  
25 talking about not just uranium fuel pellets but the whole



1 fuel assembly. As I mentioned earlier, we have informed the  
2 industry that before there are additional increases, there  
3 needs to be support for changing the burnup limits. Those  
4 are in terms of test and analysis and taking research  
5 information into account.

6 CHAIRMAN JACKSON: Where is, again, let me make  
7 sure I understand, where is the de facto cutoff today?

8 MR. HOLAHAN: Well, we don't have a national  
9 value. In effect, what the staff has done in the past is to  
10 review each fuel design and to review the proposed burnup  
11 limit that goes along with that design. So when a vendor  
12 comes in and says they have identified a new XYZ type fuel  
13 assembly, they need to propose and justify the specific  
14 limit that goes along with that fuel. So there is a  
15 spectrum also.

16 CHAIRMAN JACKSON: What is the range?

17 MR. HOLAHAN: The range tends to be in the 55 to  
18 62. I think 62 is the highest. 62 gigawatt days per metric  
19 ton uranium would be the highest, although others are 60 or  
20 below. The 50 to 60 range, I think, is typical.

21 We have said, stop where you are and we need to  
22 see -- we need to have the reactivity, LOCA and rod  
23 insertion type issues resolved and more information on the  
24 lead test assembly programs before we go any further.

25 I think one thing that is fair to say is the lead

1 test assembly programs have not been entirely effective in  
2 giving us early warning of potential problems and we are  
3 looking more closely at those. There is a tradeoff here.

4           Lead test assembly usually means that perhaps four  
5 assemblies are put in among nearly 200 in a core and those  
6 are ones that have not been tested previously so they have  
7 some aspect of them. Either they are pushing some new  
8 material or new design. We don't normally get lead test  
9 assemblies pushed to limiting burnups because they are put  
10 in nonlimiting -- they are generally put in lower power and  
11 non-rodded positions. So the program is giving us  
12 information on the performance of these new materials and  
13 new designs but it doesn't really tell you a lot, in some  
14 cases it doesn't tell you anything about how these designs  
15 are going to perform at higher burnups.

16           So we need to have, in fact, a better way of  
17 getting early information on high burnups. We may need to  
18 change our view on lead test assemblies and to maybe have  
19 them used in some staggered sort of way in which they are  
20 allowed to be put into higher burnup locations because,  
21 otherwise, you are just not going to get that information.

22           The third bullet on here really says in the  
23 absence of anything else, operating experience is going to  
24 teach us about the performance of the fuel. This is where  
25 our information on control rod problems has come from. We

1 do learn about the fuel performance from looking at fuel  
2 leakers. We do follow up on reports when there are a number  
3 of fuel problems. We take that experience back to the  
4 licensees and the vendors and have them deal with those  
5 situations.

6 Typically, we are seeing maybe one, maybe two fuel  
7 rods in an operating cycle which are failed for some reason  
8 and although that number is small, in fact it is very small  
9 compared to what was assumed in analysis and licensing of  
10 the plants. We do want to learn from that experience. Even  
11 if it is only one fuel rod out of 50,000 that failed, it  
12 failed for some reason and we want to understand the root  
13 cause. Is there some additional oxidation going on, is  
14 there a water chemistry problem, are there vibration  
15 problems associated with a given design?

16 So NRR, Research and particularly AEOD is looking  
17 at operating experience to learn from it.

18 CHAIRMAN JACKSON: Now, wasn't there about a year  
19 ago a licensee that had a fairly large number of leakers?

20 COMMISSIONER McGAFFIGAN: Calhoun.

21 MR. HOLAHAN: And I think Haddam Neck.

22 MR. CALLAN: But Fort Calhoun has particularly a  
23 particularly acute problem there.

24 MR. HOLAHAN: I think as you go back in time, you  
25 see the problems were more serious. I would say over the

1 past several years, fuel fretting and vibration has probably  
2 been the dominant cause of failures. Ralph, you have  
3 insights into that.

4 MR. MEYER: No, that's correct. The only thing I  
5 could add is even these episodes of failures you have heard  
6 mentioned, the numbers are still relatively small. My  
7 recollection is that in the last four or five years the  
8 largest single episode of fuel rod failures only involved  
9 around 25 fuel rods.

10 CHAIRMAN JACKSON: Does that change the patterns  
11 as such that it, you know, affects energy deposition at all?

12 MR. MEYER: I don't think so. The big reactivity  
13 actions that we look at are very localized. The rod drop  
14 and the rod ejection, which are the only ones that take the  
15 reactor prompt critical, I mean, these are prompt critical  
16 power bursts and they just happen in the vicinity of the  
17 single rod that is ejected or dropped and I don't think the  
18 presence of a couple leaking fuel rods in that region would  
19 have any effect on this.

20 At operating temperatures, even leakers get dried  
21 out on the inside. The moisture from the interior of the  
22 rod is expelled so it is not present under most  
23 circumstances to participate in some energetic reaction.

24 MR. HOLAHAN: Probably the primary consideration  
25 is the physical condition of the cladding. If that fuel rod

1 is leaking because it is heavily oxidized or because it has  
2 spalling on the surface or something, it is not going to  
3 perform well during a reactivity transient but it is  
4 probably not because it has a pin hole in it and it has been  
5 leaking; it is probably because that particular fuel rod,  
6 whatever is causing that fuel failure, is also causing it to  
7 have lost its ductility and to be more likely to fail.

8 We are still dealing with a relatively small  
9 number. I think it is somewhat instructive to think back to  
10 the '70s when most of these plants were licensed. We used  
11 to talk, and if you go back to the FSARs, they reference 1  
12 percent fuel failures in a lot of the analyses. Well, 1  
13 percent of 50,000 is 500. We never see 500 fuel rod  
14 leakers. It is rare to see five and it is not unusual for  
15 plants to shut down and remove one or two rods because it  
16 does produce radiation and contamination in the plant and it  
17 is a more efficient way to run the plant when it's clean.

18 CHAIRMAN JACKSON: If you look at the predicted  
19 fuel fragmentation and dispersal into the coolant, how much  
20 fuel is involved and how does that dispersal of the fuel  
21 affect reactivity?

22 MR. HOLAHAN: Let me answer in two parts.  
23 Historically, when we were concerned about fuel  
24 fragmentation, we were talking about very high energy  
25 inputs, 280 calories per gram. The primary issue, safety

1 issue associated with that, was that energy deposition is so  
2 high that not only will it rupture the cladding but it will  
3 also have molten fuel and molten fuel dispersed into the  
4 water. That not only damage that individual rod and  
5 releases its reactivity but it can produce pressure pulses  
6 in the system.

7 So that was the origin of what is the fuel  
8 fragmentation concern. And I think we see -- I mean, there  
9 are no designs out there that have any energy inputs that  
10 are anywhere near 280 calories per gram.

11 Now, we have seen in the experiments and I think  
12 realistically we could expect at relatively low energies to  
13 see cladding rupture and fuel dispersal. I think there are  
14 cases as low as 30 calories per gram, Ralph?

15 MR. MEYER: Yes, 30.

16 MR. HOLAHAN: But I think what we are seeing in  
17 those cases is the dispersal of fuel pellets that have  
18 already been fragmented, almost powdered. And what you've  
19 got is hot, 600 -- well, I still do Fahrenheit. Ralph will  
20 correct me. What you have is hot fuel but nothing near  
21 molten fuel dispersed into the water. So we don't expect  
22 that there are pressure pulses associated with that that are  
23 a concern to the reactor coolant system or the vessel.

24 So at the relatively low energy that I think the  
25 experimental data suggests that you can have fragmentation,

1 if you had a rod ejection and you had embrittled fuel, you  
2 could expect to get a relatively small amount of fuel  
3 because, in fact, what you see is a rupture of the rod and  
4 fuel from a given area dispersed into the coolant.

5 But I think that would make a very dirty primary  
6 coolant system from a reactivity point of view but it  
7 doesn't produce the pressure pulses and I think there is  
8 very little likelihood of producing any, you know, doses  
9 outside of the plant. But I think it will produce  
10 contamination problems in the plant.

11 CHAIRMAN JACKSON: There would be doses inside the  
12 plant. There are people inside the plant?

13 MR. HOLAHAN: Right. I think it would be a messy  
14 cleanup problem.

15 MR. MEYER: Keep in mind, though, that the interim  
16 criteria that we have suggested in this research letter  
17 precludes the failure of the cladding. We believe that the  
18 plants can meet the criterion where you can demonstrate that  
19 the cladding won't fail, it won't crack, it won't open up  
20 and so it would not let out any of these particulates.

21 CHAIRMAN JACKSON: At the recommended limits.

22 MR. HOLAHAN: At the 100 --

23 MR. MEYER: The 100 calorie per gram, with  
24 screening to rule out the highly spalled rods that lead to  
25 these unusually low ones like the 30 calorie.

1 CHAIRMAN JACKSON: But not at the 170.

2 MR. KING: Yes. That is an important point. We  
3 have recommended the number change from 170 to 100 but along  
4 with that, we are recommending the intent of the criteria  
5 change. Previously, the intent of the 170 was to define the  
6 point at which cladding would rupture and you would have to  
7 consider the source term. What we are recommending is the  
8 100 would be the point at which the cladding maintains its  
9 integrity and, because of fuel dispersal issues, we believe  
10 that ought to be, the intent of that criteria ought to be to  
11 remain below that so you don't have to worry about cladding  
12 integrity.

13 MR. MEYER: It is a red line, not-to-exceed limit.

14 MR. KING: Then you don't have to worry about the  
15 fuel dispersal issues, whether it is pressure pulse,  
16 contamination, flow blockage or whatever it is. So that may  
17 be a point that was missed before but that is part of our  
18 recommendation.

19 CHAIRMAN JACKSON: Okay, so that is an interesting  
20 one.

21 Commissioner McGaffigan?

22 COMMISSIONER MCGAFFIGAN: Could you tell me the  
23 relationship between the utilities and the fuel fabricators?  
24 Do fuel fabricators today have guarantees in their  
25 contracts? It is a competitive industry. Do they guarantee



1     there will be no more than one per 50,000 and if so we pay  
2     for the cost of cleanup? What is the -- how does that work  
3     as a commercial -- I am looking for some degree of self-  
4     regulation from the industry itself in this area, so how  
5     does that work?

6             MR. HOLAHAN: I believe there are warranties. I  
7     don't know the details of them. The staff doesn't normally  
8     get involved in dealing with that.

9             MR. CALLAN: There are warranties, Commissioner,  
10    and there is a lot of litigation. There is currently  
11    litigation going on between Fort Calhoun and the vendor and  
12    I am aware of others. So it is an area that the utilities  
13    pursue through the courts.

14            CHAIRMAN JACKSON: Let me make sure I understand  
15    one thing. Who has the ultimate responsibility to do the  
16    core reload analysis?

17            MR. HOLAHAN: The licensee.

18            CHAIRMAN JACKSON: And that comes under Part 50?

19            MR. HOLAHAN: Yes.

20            CHAIRMAN JACKSON: 50 what?

21            MR. HOLAHAN: It depends on how they are doing it.  
22    For example, if they are doing it within the constraints of  
23    their existing technical specifications, I would say it is  
24    part of their license and 50.36 defined what is in their  
25    technical specifications, which frequently establish by name

1 and version the codes that should be used and the criteria.

2 Where the licensee is using the vendor to do the  
3 analysis, the licensee is still responsible. For example,  
4 as a result of our Siemens inspection, we identified some  
5 difficulty with one of their fuel designs which is to be  
6 used in the Susquehanna reactor and we are meeting this week  
7 with the licensee to say, this is a licensee responsibility.  
8 The quality controls on that design are requirements that  
9 derive from the licensee's quality assurance program, which  
10 derives from Appendix B of the regulations.

11 So although we review and approve and inspect the  
12 vendors, when it comes to dealing with the responsible  
13 parties, we will go back to the licensees who are using that  
14 fuel.

15 CHAIRMAN JACKSON: So 50.36 or Appendix B  
16 completely bounds the universe?

17 MR. HOLAHAN: Well, we talked about LOCA analysis  
18 and then, of course, there is a 50.46 requirement. And  
19 probably I left something else out.

20 CHAIRMAN JACKSON: I am not so much trying to put  
21 you on the spot in terms of being able to give me a list  
22 but, rather, to know that for all licensees there is some  
23 aspect of the regulation that bounds them.

24 MR. HOLAHAN: Yes.

25 CHAIRMAN JACKSON: It is not all in license

1 conditions or just tech specs.

2 MR. HOLAHAN: I don't think that we have  
3 identified any issues that are not covered by the  
4 regulations.

5 CHAIRMAN JACKSON: Where would it be if it is not  
6 in the license itself?

7 MR. HOLAHAN: If it's not in the license, meaning  
8 a specific license condition, those are technical  
9 specifications, then I think it's in the general that says  
10 the plant is going to be run in accordance with the  
11 regulations. That is part of the license, and the  
12 requirements are in the regulations.

13 MS. CYR: I mean, are the peak cladding  
14 temperatures that are a part of 5046 in the ECCS which has  
15 the 2,200 degrees and is specified there which has a big  
16 impact on this, most of it as I understand it, and I can't  
17 speak authoritatively, is in the tech specs, and it's mostly  
18 in terms of the way their license conditions are specified  
19 that enough criteria of various kinds which bound each  
20 reload and then the analysis that they have to do -- deviate  
21 from that as they move to a new one.

22 MR. HOLAHAN: And there are probably some examples  
23 that are only in the FSAR and not specifically in the tech  
24 specs.

25 CHAIRMAN JACKSON: Okay. I mean that's actually

1     what I was trying to get at, whether some of this is in  
2     parts of the licensing basis.

3             MR. HOLAHAN:   Yes.

4             CHAIRMAN JACKSON:   That are not in the tech specs.

5             MR. HOLAHAN:   Yes.   I think we already talked  
6     about slide 19 with the research work on the LOCA criteria,  
7     and here again is as with the rod-ejection issue there's the  
8     potential need for visual inspection if the condition of  
9     fuel going into the reactor is going to play an important  
10    role in how it performs later.   That may or may not be the  
11    case, but we'll deal with that as the issue is developed.

12            [Slide.]

13            MR. HOLAHAN:   Slide 20 summarizes the issue of  
14    incomplete control-rod insertions.   I think recently we've  
15    been dealing with Wolf Creek and South Texas and their  
16    experience.   We issued a bulletin back in last year to get  
17    information from all the U.S. -- well, all the Westinghouse-  
18    designed plants.   In addition I think it's fair to say that  
19    foreign reactor experience probably led the U.S. experience  
20    in this area, and both we in research and AEOD have been  
21    following that information with some of our individual  
22    discussions with those regulators in those countries, and  
23    also in some international-type meetings.   And I think AEOD  
24    has additional details on that if some questions arise.

25            In effect what we did last year was to tell plants

1 with a Westinghouse design that we wanted more information  
2 to verify that their control rods were inserting as  
3 required, and that was a bulletin that ran from I think  
4 about the spring of last year through the end of the year.  
5 It was a one-time bulletin that sort of had a deadline on  
6 it. In that period 35 tests were done. Some tests were  
7 done more than once at a given plant, so 35 tests is not  
8 exactly 35 plants. What we found is that in all cases the  
9 technical specifications were met, and those specifications  
10 are on the timing of the rod insertion. But what we also  
11 called for in the bulletin was more sensitive measures of  
12 how the control rods were behaving, early indication of  
13 potential problems. One thing that was looked at on the  
14 slide is called drag criteria, which is the amount of force  
15 necessary to pull a rod out of an inserted position. What  
16 we found is a number of cases, and I'd be a little more  
17 specific, what it refers to on the slide is nine tests, and  
18 what we actually found is there are really two areas of  
19 interest.

20 In the bottom of the fuel assembly, the last few  
21 inches, there's something called a dash pot, where the area  
22 is reduced intentionally to slow the rod down as it gets to  
23 its final resting position. So one would expect that to be  
24 a tighter fit than the rest of the rod, the rest of the  
25 thimble tube where the rod goes down. In fact the thimble

1 tube is the more important area because the last few inches  
2 do not have much reactivity associated with them.

3 What we found from those 35 sets of tests was  
4 three plants which were above the drag criteria in the dash  
5 pot, and these are criteria established by Westinghouse as  
6 part of the design of the fuel assemblies. We found another  
7 six where there were unusually high values which I would say  
8 were precursors to exceeding the criteria. In the thimble  
9 tube area, that is the major part of the fuel assembly, we  
10 saw six plants that were above the criteria and another  
11 three where it was higher than expected. So these were  
12 early warnings that even though that fuel is still within  
13 the specifications and doesn't have a safety problem, we're  
14 getting early warnings that those need to be looked at.

15 Recently the South Texas plant, which has 14-foot  
16 core as opposed to the 12-foot cores in all the other  
17 plants, and which appears to be more susceptible to  
18 difficulties with inserting the control rods, Unit 1 did  
19 tests in January, and Unit 2 did tests in February. The  
20 Unit 1 tests were mid-cycle tests which were done at the  
21 staff's request, and they had two rods stick at six steps,  
22 which means within about 4 inches of the bottom of the fuel  
23 assembly -- that is to say, it was completely inserted  
24 except for the last about 4 inches. And two additional rods  
25 which we call no-recoil, which is to say when they reached

1 the bottom of the fuel assemblies, they didn't bounce, and  
2 one thing we look for is you can tell something about the  
3 velocity that the fuel rods -- excuse me, the control rod is  
4 inserting by whether it bounces when it gets to the bottom.  
5 So these are even precursors to precursors in a sense of  
6 degraded performance. Unit 2 had four rods stuck at six  
7 steps, and one rod stuck at 12 steps. So they are  
8 continuing to see what I would say is degraded performance,  
9 and the staff is requiring the South Texas plant to do  
10 additional mid- and interim-cycle testing.

11 Lastly on the subject we have a followup bulletin  
12 under review. We have a date with the CRGR in the near  
13 future which will basically identify for rodged assemblies  
14 we would suggest guidelines for fuel management, additional  
15 testing and analysis, and also give the licensees the  
16 alternative to propose some other approach to dealing with  
17 this issue. So we would put out a letter asking them what  
18 they are doing in this area with some suggested guidelines  
19 that we've got.

20 So that's basically our plan for dealing with the  
21 ongoing issues with the combination of research activity and  
22 dealing directly with the licensees. I think in the spirit  
23 of getting a little bit back on schedule --

24 CHAIRMAN JACKSON: It's impossible. The meeting  
25 ended three minutes ago.

1 MR. HOLAHAN: Well, not getting additionally  
2 beyond I think AEOD volunteered to skip their presentation  
3 unless you have questions on the foreign experience.

4 CHAIRMAN JACKSON: What are your big points?

5 MR. ORNSTEIN: Well, the most important point that  
6 I'd like to make is the fact that a lot of the problems that  
7 have been arising in the States have had early warnings  
8 overseas, and basically I refer to it as the cat -- you  
9 know, the canary in the mine. Some of the issues that we've  
10 seen unfolding at South Texas and Wolf Creek were presaged  
11 by events overseas. Again, there's no single one-to-one  
12 correspondence between a particular plant and its fuel and  
13 fuel management here versus the States.

14 However, there are important features that we're  
15 able to piece together, and as a result, we try to keep up  
16 on it and see if there are certain aspects of it that are  
17 important, like, for example, AEOD has been present in  
18 virtually all the meetings that have been held with  
19 Westinghouse folk and the people with Westinghouse plants  
20 have had problems which the Bulletin 9601 came out about.  
21 We've been continually pushing for the interrelationship  
22 between people in the States and plants overseas, and  
23 Westinghouse in turn has indeed, you know, followed and  
24 tried to be, you know, connected.

25 When it comes to the French fuel, we have



1 different issues, but still it's an important information  
2 flow that has been very helpful in our understanding of the  
3 events.

4 COMMISSIONER MCGAFFIGAN: Let me just ask, and  
5 this, maybe it goes back to Mr. Holahan, on graph 24 or  
6 chart 24 it talks about restrictions placed overseas, and it  
7 says U.S. guidelines presently being considered. What are  
8 our guidelines -- I think you just were referring to them --  
9 what are our guidelines likely to say now that I have  
10 numbers in front of me from other countries? Are we likely  
11 to choose a burnup limit or require mid-cycle tests or where  
12 are we headed? If you're the one to answer it, that's fine.

13 MR. ORNSTEIN: Well, no, actually in the  
14 licensing, NRR indeed is the right organization. However, I  
15 want to caution you that, you know, the types of fuels that  
16 we see in some of these plants are not necessarily the same.  
17 For example, there's a French fuel that appears in the  
18 Belgian plants. They also have a similar Westinghouse fuel  
19 that is performing a little bit better, and it's not a one-  
20 to-one relationship. I think --

21 CHAIRMAN JACKSON: No, but even saying that, I  
22 think that there's a broader way, if I may phrase the  
23 Commissioner's question, I mean, clearly these restrictions  
24 fall into certain categories having to do with burnup, you  
25 know, drop tests, et cetera, and one could ask the question

1     irrespective then of the specific numbers, whether we're  
2     moving along lines in these particular areas, and to the  
3     degree that you can give some specificity I think it would  
4     be useful.

5             MR. ORNSTEIN: Well, the important thing is that  
6     there's been an evolution at these foreign plants as to --

7             CHAIRMAN JACKSON: No, no, no, no. You're missing  
8     my point. My question is really -- Mr. Holahan.

9             MR. HOLAHAN: I understand, in the licensing  
10    aspects. Okay.

11            CHAIRMAN JACKSON: Right. That's what I'm talking  
12    about.

13            MR. HOLAHAN: I understand. In our draft of the  
14    bulletin supplement we have taken in fact what Westinghouse  
15    has suggested as guidelines and we're considering those or a  
16    modification of those. What we think is, at least to this  
17    point, probably not a single value of burnup limit is  
18    appropriate. When you go back and begin to understand the  
19    root cause of the problem, what it looks like is a burnup  
20    limit for 12-foot fuel and for 14-foot fuel probably ought  
21    to be different, because the 14-foot fuel assemblies are  
22    less rigid, and are more easily distorted.

23            In addition, fuel -- additional grid spacers,  
24    which are -- make the fuel assemblies more rigid and less  
25    capable of distorting, probably also affects the appropriate

1 burnup. So what I imagine is we'll come out with a  
2 guideline or maybe three separate guidelines, or at one  
3 point we had six separate guidelines. But I think we'll  
4 probably be down around three, that says for a certain type  
5 of fuel a burnup limit of x, and for a different type of  
6 fuel, burnup limit of y and z. And I could tell you that I  
7 think right at the moment that x, y, and z are somewhere  
8 between 25 and 40. Okay? But as recently as yesterday I  
9 think the numbers changed, so -- and effectively I think  
10 this is one of those generic communications that we'll put  
11 out for public comment.

12 CHAIRMAN JACKSON: When are you expecting to  
13 propagate that generic communication?

14 MR. HOLAHAN: Let me ask if -- it's fairly close.  
15 Do we have a date with CRGR?

16 MS. CHATTERTON: The earliest date we would meet  
17 with CRGR is April 8.

18 MR. HOLAHAN: April 8.

19 COMMISSIONER McGAFFIGAN: Are you also thinking of  
20 mid-cycle drop tests. You've been doing it in South Texas.  
21 Would that become a generic refinement?

22 MR. HOLAHAN: Yes. I think what we're thinking  
23 about is an integral approach that says at certain burnups  
24 you don't need to do mid-cycle tests. At higher burnups, in  
25 fact the numbers we've been talking about are not

1 necessarily absolute prohibitions, there could be some  
2 trigger that says if you're above 30,000 megawatt-days per  
3 ton, that triggers the need for an additional mid-cycle  
4 test, as opposed to an absolute prohibition for that to be a  
5 rodDED position.

6 CHAIRMAN JACKSON: But in some sense these  
7 specific things deal with specific issues having to do with  
8 rod insertions.

9 MR. HOLAHAN: Yes.

10 CHAIRMAN JACKSON: But there are a whole host of  
11 other considerations that would play into --

12 MR. HOLAHAN: Yes.

13 CHAIRMAN JACKSON: Some modification in terms of  
14 restrictions. Is that not correct?

15 MR. HOLAHAN: Yes, that's correct.

16 CHAIRMAN JACKSON: They'd be dealing with the LOCA  
17 kinds of analyses.

18 MR. HOLAHAN: Yes.

19 CHAIRMAN JACKSON: These energy deposition  
20 considerations that we were talking about.

21 MR. HOLAHAN: Yes.

22 CHAIRMAN JACKSON: Okay.

23 MR. HOLAHAN: I think we're going to turn to Dr.  
24 Paperiello.

25 DR. PAPERIELLO: We'll jump to slide 27.

1 [Slide.]

2 DR. PAPERIELLO: Tom summarized the overall NMSS  
3 issues. The front end of the fuel cycle with respect to  
4 criticality for enrichments above 5 percent, and the back  
5 end of the fuel cycle for disposal or in the storage of  
6 spent fuel with high burnup. The current approvals for the  
7 fuel fabricators don't exceed 5 percent enrichment in U-  
8 235. The reason -- and of course current manufactured fuel  
9 is not above 5 percent, and if high burnup -- to achieve  
10 high burnup we'd have to go above 5 percent. Some of the --  
11 we would have to amend the licenses. And the issues on  
12 criticality is computer codes used for criticality have been  
13 tested and benchmarked against certain critical experiments.  
14 There are a lot of critical experiments at 5 percent and  
15 lower. There are a lot above 80 percent. There are very  
16 few in between.

17 We don't have a well-established basis to  
18 extrapolate either. We need benchmark data at the  
19 enrichments we want to consider, or we have to build enough  
20 conservatisms into our criticality calculations to allow  
21 extrapolation. That is being worked on. We have research  
22 is looking into the availability of benchmark data,  
23 particularly overseas. We do believe the data exist. So  
24 that's one set of issues.

25 The issue of criticality goes across the whole

1 range of both fuel-production facilities as well as packages  
2 to transport uranium oxide, to pellets and finished fuel  
3 assemblies.

4 [Slide.]

5 DR. PAPERIELLO: The other issue, if we go to  
6 slide 28, is the issues on transportation and dry storage.  
7 The two issues, and it drives a number of things, are again  
8 very similar to the NRR's issues, the radionuclide  
9 inventory, because this will determine how we do the  
10 shielding and whether shielding is adequate. The cooloff  
11 time, typically fuel is cooled for 5 years before it's put  
12 in a cast. They give rise to temperature and the long-term  
13 cladding integrity. If the cladding is running at a hotter  
14 temperature, there is the potential for creep and for  
15 oxidation. So we do not have an effort with research  
16 currently. We propose to get an effort at research, but in  
17 preparing for this meeting, it was clear that the NRR issues  
18 in this area and my issues overlap and they will be  
19 coordinated.

20 COMMISSIONER MCGAFFIGAN: Could I ask on this  
21 chart, you say spent-fuel vendors applied for the average  
22 burnups up to 65 gigawatt-days per metric ton. That's --  
23 we're talking in terms of what actually is in reactors 60 or  
24 62 for peak, and therefore 40 or 45 for average batch,  
25 right, so in some sense if we've been doing -- the cask

1 folks are well ahead of the industry if they've been  
2 applying at this --

3 DR. PAPERIELLO: Right now I'm just -- right now  
4 we have an application in, but it's not been approved.  
5 Right now our approvals range in the order of about 40.

6 COMMISSIONER McGAFFIGAN: They're in the forties.  
7 Thank you.

8 CHAIRMAN JACKSON: Go ahead.

9 DR. PAPERIELLO: I'm finished.

10 CHAIRMAN JACKSON: That was your presentation?  
11 All right.

12 Who's the wrap-up.

13 MR. KING: I'm the wrap-up.

14 COMMISSIONER McGAFFIGAN: Could I -- before --  
15 what are the implications for Yucca Mountain? I mean, of  
16 going to higher burnups in the sense -- any analyses you  
17 have to do to license a long-term storage facility.

18 DR. PAPERIELLO: I don't know. In fact as I was  
19 sitting here that was a question I asked myself. I will  
20 have to check. I would expect it to be the thermal issue.  
21 I think in terms of the enrichment and the effect of  
22 radionuclide composition is going to be bounded by the  
23 putting of either vitrified plutonium or high-enriched, you  
24 know, the submarine reactor cores in Yucca Mountain would  
25 certainly dominate, but the temperature issue I don't know,

1 but I will check. That occurred to me in this presentation.

2 CHAIRMAN JACKSON: Okay.

3 MR. KING: Let me try and wrap up in 60 seconds if  
4 we can. Slide 32 and 33 are the summary.

5 [Slide.]

6 MR. KING: The main points I wanted to come back  
7 to were one, there's a lot of activities under way to deal  
8 with the high-burnup fuel issues. They cut across a number  
9 of our criteria and they cut across the offices. We have  
10 activities and plans to deal with the in-reactor issues.  
11 We're working with NMSS to develop plans to deal with the  
12 out-of-reactor issues. The risk implications of the high-  
13 burnup fuel performance. Our work is really geared toward  
14 trying to maintain low risk from high-burnup fuel, and we  
15 feel that that can be achieved, although there's still some  
16 issues that need to be verified, particularly dealing with  
17 the new phenomena we're seeing of fuel dispersal and higher  
18 source terms and so forth. But what we're doing is we  
19 illustrate it with the criteria, trying to develop criteria  
20 that deal with those issues in a way that they don't  
21 contribute any additional risk or any new types of accidents  
22 to the plant.

23 In terms of concerns on slide 33 -- maybe concerns  
24 is maybe a little too strong a word -- we feel cooperation  
25 with industry is important, and it's two-way cooperation.



1 We've got a lot of our data from foreign sources,  
2 experimental data. A lot of the details of that are  
3 proprietary. We've been working with our foreign partners  
4 to try and get that released to industry. Our industry's  
5 very interested in that data. We've done that so far  
6 through things like having special sessions at the water  
7 reactor safety meeting, in a special issue of the Nuclear  
8 Safety Journal. We'll continue to try and get that data  
9 released.

10 We had a concern early on that industry was not  
11 doing any experimental work in the transient area -- they do  
12 a lot of steady-state work -- although we now have made some  
13 progress in that area, at least reached an understanding  
14 with DOE and EPRI to gain access to high-burnup fuel samples  
15 that we could use in our program at Argonne that'll be  
16 dealing with the LOCA performance.

17 We also made some progress in getting access to  
18 industry steady-state data. There's a program called the  
19 nuclear fuel industry research program that had been kept  
20 proprietary. We now have got an agreement from EPRI to have  
21 access to those reports.

22 Finally on the horizon we talked about DOE spent-  
23 fuel minimization program. There's potential MOX fuel. At  
24 this point we don't have any resources budgeted to deal with  
25 those, although in the MOX area we are trying to do some

1 homework, and I think in the spent-fuel minimization  
2 program, it would probably be wise to think along the lines  
3 of a white paper to see what the issues are and the  
4 implications are to that.

5 CHAIRMAN JACKSON: Let me ask you a couple of  
6 questions. Can we go back to this issue of the current  
7 licensing basis vis-a-vis fuel design? How do we ensure  
8 that it is maintained when it is not in the tech specs?

9 MR. HOLAHAN: Well, in some cases it's in the  
10 FSAR, but I think we know that there are cases in which an  
11 important part of the licensing basis is only in some  
12 topical reports and the staff's review and approval of  
13 those. The staff has generated a number of recommendations  
14 based on the Maine Yankee lessons learned activity that I  
15 think we owe to the Commission this week or the end of this  
16 month, pretty close. That's a combination both of the  
17 staff's internal review of the Maine Yankee lessons learned  
18 plus the Ed Jordan's ISAT team had a number of  
19 recommendations related to the subject.

20 My recollection is it is about half, 11 of the 24  
21 staff recommendations in this area go to the point of how  
22 are codes reviewed and approved and how do you make sure  
23 that it is in the licensing basis.

24 I think we have already started to move in that  
25 direction. But I think it is fair to say that in the past

1     there have been examples in which code reviews and  
2     licensees' commitment with respect to code calculations or  
3     some of these other issues we have been talking about today  
4     are in letters or topical reports and they are not captured  
5     in the FSAR. So they are lower level commitment documents.

6             One of the things we have identified is an  
7     activity to assure that when we review and approve things in  
8     the future that approval of the topical reports are clear,  
9     that the issues are in those reports and that when licensees  
10    use these, they get them into either license conditions or  
11    in the FSAR.

12            So I can't promise that is the way they were in  
13    the past. I think we know of examples where they weren't.  
14    But I think we have recognized it and are moving in the  
15    direction.

16            CHAIRMAN JACKSON: Given that the Commission is  
17    considering papers coming out of the Millstone lessons  
18    learned and 50.59, are the activities and the  
19    recommendations in those papers going to allow us to capture  
20    what needs to be captured relative to this issue with  
21    respect to the codes, fuel design?

22            MR. HOLAHAN: Yes. I would say the combination of  
23    the 50.59 Millstone and Maine Yankee lessons learned,  
24    together, definitely, I think, cover this issue.

25            CHAIRMAN JACKSON: How?

1           MR. HOLAHAN: Well, there are a series of specific  
2 recommendations which I just happened to bring with me for  
3 things like establishing standard in format guide for  
4 topical reports, for assuring that the staff's questions and  
5 responses to those are put in the approved versions of  
6 topical reports, sample applications are all --

7           CHAIRMAN JACKSON: These are things coming out of  
8 Maine Yankee.

9           MR. HOLAHAN: Yes.

10          CHAIRMAN JACKSON: I am saying to you, are they  
11 included in the actions that are before the Commission for  
12 the Millstone lessons learned, which is focused on the  
13 current licensing basis issues?

14          MR. HOLAHAN: I think they have been coordinated  
15 and both are owed to the Commission. But they are not all  
16 in one document but they are all in the staff's plans.

17          CHAIRMAN JACKSON: Well, that is not quite the  
18 answer to the question I am trying to understand.

19          MR. MIRAGLIA: Madam Chairman, in terms of  
20 capturing commitments, I think the commitment discussion in  
21 the Millstone Part Two would cover this. The specifics on  
22 the codes are more directly related to Maine Yankee but the  
23 efforts that we are doing in the captured commitments is to  
24 make sure they are reflected in appropriate places, the  
25 licensing basis, I think, would encompass that.

1 CHAIRMAN JACKSON: All right.

2 Let me just ask a separate kind of question. Is  
3 the fuel designed to withstand the blowdown loads for a  
4 large break LOCA and how is that affected by some of the  
5 embrittlement issues and so forth that we are talking about?

6 MR. HOLAHAN: Well --

7 MR. MEYER: The answer is, yes.

8 MR. HOLAHAN: The answer is, yes. But most of  
9 what we have talked about is the heatup of the fuel and the  
10 LOCA concerns are not really during the blowdown.

11 CHAIRMAN JACKSON: That's right.

12 MR. HOLAHAN: And so these are really during the  
13 heatup phase.

14 CHAIRMAN JACKSON: Exactly.

15 MR. HOLAHAN: But, yes, the criteria we have for  
16 the fuel, structural integrity of the fuel assemblies and  
17 the stress and strain limits and all of that do take LOCA  
18 loads into account.

19 CHAIRMAN JACKSON: Are we explicitly considering  
20 that as we look at this issue of embrittlement and loss of  
21 ductility, et cetera, in the high burnup situation?

22 MR. MEYER: We are looking at that in the research  
23 program but I have to say that we really haven't initiated  
24 that part of the work. We identified it almost over two  
25 years ago --

1 CHAIRMAN JACKSON: Is it unimportant?

2 MR. MEYER: No, it is not unimportant. In the  
3 deep, dark past there were generic evaluations done, not  
4 only for the blowdown load but in combination with  
5 earthquake loads and those have been documented and  
6 have -- that seemed to relieve all concern until we get to  
7 the point where we understand that the whole fuel assembly  
8 will now have less ductility and it may have lower fracture  
9 toughness and the kind of things that would come into that  
10 analysis. We do plan to review that but we have to get the  
11 mechanical properties from our measurements before we have a  
12 basis for doing that assessment.

13 CHAIRMAN JACKSON: Well, I am not at all talking  
14 about what has to come first. I am really specifically  
15 asking you whether or not you are considering the issue of  
16 blowdown loads or planning to revisit it as part of what you  
17 are doing?

18 MR. KING: Yes, we are planning to do it. We  
19 haven't gotten that far yet.

20 CHAIRMAN JACKSON: All right.

21 Commissioner Rogers?

22 COMMISSIONER ROGERS: I don't have any additional  
23 comments.

24 CHAIRMAN JACKSON: Commissioner McGaffigan?

25 COMMISSIONER MCGAFFIGAN: No additional questions.

1 CHAIRMAN JACKSON: All right.

2 Thank you.

3 I would like to thank the staff for a very  
4 informative and long briefing. Long because of us. And I  
5 would urge the staff to continue its cooperation in  
6 international experiments. It seems like that is an  
7 important source of data and information for us, in order to  
8 establish failure limits for high burnup fuel and reactivity  
9 insertion accidents. But operational experience, as we have  
10 been discussing for the last two hours, clearly suggests  
11 that high burnup fuel has effects that go beyond reactivity  
12 insertion and I am going to urge you to do what you have  
13 already told us you are doing, namely to ensure that you  
14 have the appropriate research and other tools in place to  
15 address emerging issues that relate to core and fuel designs  
16 and plant operations.

17 You know, the agency's licensing criteria which,  
18 you know, you are expecting will hold up to a certain extent  
19 beyond the current burnups is based on 1970s experience and  
20 to burnups that were to less than 30 gigawatt days per ton.  
21 So you say you are and so I am saying that you should  
22 reassess our fuel regulatory guidelines and licensing  
23 criteria covering not only reactivity insertion accidents  
24 but the design basis accidents we have been talking about  
25 and LOCAs.

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1           But the thing I would particularly encourage the  
2 staff to do is to continue not only gathering data and  
3 information but integrating it on as much of a real time  
4 basis as possible and to confirm that plants are safe and in  
5 compliance with their licensing bases.

6           The final comment is that I am taking off from  
7 what Mr. Miraglia said, that all of these various lessons  
8 learned that we have done and what the staff, the Commission  
9 has been asked to look at and approve will ensure that we  
10 capture what we need to capture in this area, vis-a-vis fuel  
11 design in the licensing basis.

12           So if there are no further comments, we are  
13 adjourned.

14           [Whereupon, at 11:50 a.m., the briefing was  
15 concluded.]

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CERTIFICATE

This is to certify that the attached description of a meeting of the U.S. Nuclear Regulatory Commission entitled:

TITLE OF MEETING: BRIEFING ON HIGH-BURNUP FUEL ISSUES -  
PUBLIC MEETING

PLACE OF MEETING: Rockville, Maryland

DATE OF MEETING: Tuesday, March 25, 1997

was held as herein appears, is a true and accurate record of the meeting, and that this is the original transcript thereof taken stenographically by me, thereafter reduced to typewriting by me or under the direction of the court reporting company

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