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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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MEETING

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

SUBCOMMITTEE ON REACTOR FUELS

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WEDNESDAY

APRIL 21, 2004

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ROCKVILLE, MARYLAND

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The Subcommittee met in the Commissioners' Conference Room O-1G16 at One White Flint North, 11555 Rockville Pike, at 8:30 a.m., Dana A. Powers, Chair, presiding.

COMMITTEE MEMBERS:

DANA A. POWERS	Chair
MARIO V. BONACA	Member
THOMAS KRESS	Member
GRAHAM M. LEITCH	Member
VICTOR H. RANSOM	Member
SPYROS TRIAFOROS	Consultant
RALPH CARUSO	Designated Federal Official

NRC STAFF PRESENT:

Ralph Landry	NRR, Reactor Systems Branch
Steve LaVie	Probabalistic Safety Assessment Branch
Robert Martin	NRR
Ralph Meyer	RES
Undine Shoop	NRR, Reactor Systems Branch

ALSO PRESENT:

Patrick Blanpain	Framatome
Burt Dunn	Framatome
Jim Eller	Duke Power
Edwin Lyman	BREDL
George Meyer	Framatome
Steve Nesbit	Duke Power

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

2 Time: 9:29 a.m.

3 CHAIRMAN POWERS: The meeting will now
4 come to order. This is a meeting of the Advisory
5 Committee on Reactor Safeguards, Subcommittee on
6 Reactor Fuels. I am Dana Powers, Chairman of the
7 Subcommittee.

8 Subcommittee members in attendance are:
9 Mario Bonaca, Tom Kress, Victor Ransom, Graham Leitch.
10 Consultant in attendance is Spyros Triaforos.

11 The purpose of the meeting is to discuss
12 the application by Duke Energy for authorization to
13 load four mixed oxide fuel lead test assemblies into
14 the reactor core of the Catawba Nuclear Station. The
15 subcommittee will hear presentations by and hold
16 discussions with representatives of the NRC staff,
17 Duke Energy, Framatome and other interested parties
18 regarding this matter.

19 The subcommittee will be gathering
20 information, analyzing relevant issues and facts to
21 formulate proposed positions and actions, as
22 appropriate, for deliberation for the full Committee.

23 Ralph Caruso is the designated Federal
24 official for this meeting.

25 The rules for participation in today's

1 meeting have been announced as part of the notice of
2 this meeting previously published in the Federal
3 Register on April 9, 2004. Portions of this meeting
4 may be closed for the discussion of proprietary
5 information.
6 A transcript of the meeting is being kept
7 and will be made available as stated in the Federal
8 Register notice. It is requested that speakers first
9 identify themselves and speak with sufficient clarity
10 and volume so they can be readily heard.
11 We received one request from a member of
12 the public to make an oral statement. We have
13 established an agenda for today's meeting that allows
14 for members of the public to provide their comments
15 early in the day, so the members can consider these
16 questions throughout the day on issues that are of
17 interest to the public.
18 Members of the public will also be
19 afforded an opportunity to comment at the end of the
20 day following the licensee and staff presentations.
21 The purpose of this meeting is limited.
22 We are limited to the consideration of the reactor
23 safety aspects of the application by Duke Energy to
24 load four LTAs in the Catawba core.
25 We do not intend to discuss the MOX fuel

1 fabrication facility that is planned to be built at
2 Savannah River or the safety and security aspects of
3 fuel transport and eventual disposal or the safety
4 aspects of any plans to load batch quantities of MOX
5 fuel into the Catawba reactors. Batch loading of the
6 MOX fuel will be the subject of future licensing
7 applications.
8 We have a fairly lengthy agenda that I
9 hope we can move through expeditiously. Contrary to
10 rumors that I know abound, all members of the
11 subcommittee can, in fact, read the Vu-Graphs. So you
12 can move expeditiously through it.
13 All members of the subcommittee are
14 relatively aware of the background of this
15 information. So you can truncate comments on the
16 background and move to the heart of your presentation.
17 I encourage you to emphasize the points you want to
18 make clearly at the beginning, and then move on to
19 your discussion for justification on those.
20 Do any of the members of the subcommittee
21 care to make opening comments?
22 MR. CARUSO: I would just like to
23 reiterate one point that I made before the meeting
24 opened. No food or beverage is allowed in this room.
25 It is the Commission's meeting room, and their rules

1 are you are not allowed to eat, drink, smoke, do
2 anything illegal in this room. So please honor that
3 request.
4 CHAIRMAN POWERS: And, presumably, the
5 craps game in the back corner will have to stop now.
6 With that, I will call upon Mr. Robert
7 Martin of the Office of Nuclear Regulation to begin.
8 MR. MARTIN: Good morning. I am Bob
9 Martin. I am the Project Manager in the Office of
10 Nuclear Reactor Regulation for the review of MOX Lead
11 Test Assemblies at Catawba Station.
12 We have members of the NRC technical staff
13 with us today, which I will introduce them and their
14 areas later in the agenda when we get to the NRC
15 staff's presentation.
16 As you shall soon hear in more detail from
17 the licensee, the license amendment application that
18 we are discussing today is part of an ongoing program
19 between the United States and the Russian Federation
20 for the disposition of excess weapons grade plutonium.
21 That program in the United States has two
22 major elements, one having to do with the fuel
23 fabrication facility and one having to do with the
24 irradiation of the material in commercial power
25 reactors. As you mentioned, I believe, the fuel

1 fabrication facility has been before the committee on
2 previous occasions.
3 CHAIRMAN POWERS: Over and over again.
4 MR. MARTIN: The goal of the program is to
5 dispose of excess weapons grade material by converting
6 it into a MOX fuel and irradiating it in a commercial
7 power reactor.
8 The application for amendment of the
9 Catawba operating license was submitted on February
10 27, 2003, a little bit over a year ago. That
11 application initially also included Duke's McGuire
12 station, and that was subsequently withdrawn from the
13 application.
14 Numerous supplements have been submitted
15 since that time, which are identified at the end of
16 the safety evaluation. The staff issued its safety
17 evaluation on April 5th of this year.
18 The issuance of the safety evaluation does
19 not constitute final agency approval of the
20 application. Any NRC approval of the application will
21 also require completion of other matters, including
22 results of the staff's environmental and physical
23 security reviews, etcetera.
24 CHAIRMAN POWERS: It seems to me, I
25 received a letter that I probably cannot find that

1 suggested that the actual core that is going to hold
2 the LTAs will be different from the one addressed in
3 the SER.
4 MR. MARTIN; I was just about to get into
5 that.
6 CHAIRMAN POWERS: Okay.
7 MR. MARTIN: Okay. The staff's review, as
8 reported in that safety evaluation, was conducted on
9 the basis of what was in the application with its
10 supplements, which are basically two fuel designs in
11 that reactor core that would contain the MOX lead test
12 assemblies.
13 Recently, the staff has learned of the
14 licensee's plans that would include a third fuel
15 design in that core. The licensee addressed this in
16 its letter of April 16th. The staff and the licensee
17 plan to meet to discuss this issue in further detail
18 at the end of this week, two days from now.
19 At this time, the staff has not determined
20 the extent to which this new information and the
21 licensee's responses to it impacts the staff's
22 conclusions reached in the SE.
23 I would say that the range of the impacts
24 could range from -- As we learn more from the licensee
25 about that additional fuel design, we could learn that

1 the analyses that the licensee has already performed
2 bound that fuel design.
3 The other extent of the range is that we
4 could find that matters arise which require additional
5 analyses or whatever from the licensee. We don't know
6 that yet. That would be the purpose of Friday's
7 meeting with them.
8 CHAIRMAN POWERS: One of the problems I
9 face is I have to make a recommendation to Mr. Bonaca
10 on whether to schedule anything for his May meeting.
11 He gets irked with me if he finds that I am wasting
12 his time of his committee. Are we going to be in a
13 position to utilize the ACRS's time effectively on
14 this in May?
15 MR. MARTIN: I don't know that yet. Our
16 position at this time is that we are going to
17 determine the impact of the new information on the
18 conclusions that we presented in the safety
19 evaluation, and we will issue a supplement to the SE
20 as appropriate.
21 DR. KRESS: The audio is not working?
22 We'll just have to speak up.
23 I was wondering what were the differences
24 in this new design. so we might even have an opinion
25 as to whether it will have a substantial effect on the

1 various parts of the SE?

2 MR. MARTIN: We know some of the

3 differences in not a deeply informed way. I think

4 Duke's presentation will cover that in much more

5 detail.

6 That concludes my comments, my opening

7 comments.

8 DR. LEITCH: Just one general question:

9 The scope has been narrowed to just Catawba, not

10 McGuire, from what I understand?

11 MR. MARTIN: That is correct.

12 DR. LEITCH: And I think it said Catawba

13 1, and I'm a little confused if it is 1 and 2 or if it

14 is just one unit that we are considering, or is it

15 both units?

16 MR. MARTIN: Well, the application, in

17 licensing space Duke has left it open such that their

18 application applies to either unit. The LTAs would be

19 put into one or the other.

20 DR. LEITCH: But not both, as far as this

21 discussion is concerned?

22 MR. MARTIN: But not both. That's

23 correct. Four lead test assemblies would go into one

24 of the two units.

25 DR. LEITCH: All right. Thank you.

1 CHAIRMAN POWERS: Any other questions for
2 Mr. Martin? Seeing none, I will now turn, I think, to
3 Mr. Lyman, Dr. Lyman. Come sit with us, Ed. Welcome,
4 sir.
5 DR. LYMAN: Good morning. It is always a
6 pleasure to be here. Is this live? I'll speak up.
7 How is this?
8 Well, as always, it is a pleasure to be
9 here talking to the subcommittee on MOX. I've done it
10 a few times now. I am going to give an overview of
11 some of the issues that the Blue Ridge Environmental
12 Defense League has raised in its intervention against
13 Duke's LTA application.
14 The Union of Concerned Scientists is
15 assisting BREDL in this effort, and I am just going to
16 discuss some of the issues that we think are required
17 to resolve before this amendment can be granted. Can
18 I have the next slide, please?
19 The only thing to observe here is that the
20 application really has two parts. One is the safety
21 environmental application for the license amendment,
22 the request for the license amendment to use the MOX
23 LTAs at Catawba 1. The other part is a request for
24 exemption from certain regulatory requirements having
25 to do with the security of the stored MOX fuel. May

1 I have the next slide, please.

2 As I said, Union of Concerned Scientists

3 is assisting BREDL, Blue Ridge Environmental Defense

4 League, in challenging the LTA LAR and the security

5 exemption request, and in this context we have entered

6 both security related contentions which are being --

7 that proceeding is being conducted in a closed

8 session, because there is safeguards information

9 involved, and non-security related contentions which

10 are the main subject of this meeting today. Next

11 slide, please.

12 On March 5th the Atomic Safety Licensing

13 Board in this case admitted three of BREDL's non-

14 security related contentions after reframing the large

15 number that BREDL had submitted and classifying them

16 into three bins that are grouped by relevant issues.

17 In addition, there was an order on the

18 security contentions, which was last week. I

19 understand there will be a public version of that, but

20 it is not out yet. So I am not going to say anything

21 about that order.

22 This is an unusual proceeding, because

23 Duke has asked the NRC to make a decision on this

24 application by August 2004, and the timetable here is

25 driven by a request from the Department of Energy,

1 National Nuclear Security Administration, which
2 actually wants the decision in hand before it ships
3 plutonium from the United States to France for
4 fabrication of the lead test assemblies at the
5 Cadarache plant.
6 This is because the plant is already on
7 borrowed time. France decided to shut it down last
8 year because it is not seismically qualified, but it
9 is limping along doing some clean-up work and waiting
10 for this last mission.
11 As a result of the ASLB's attempt to
12 accommodate this accelerated timetable, the
13 adjudicatory proceeding schedule is in a highly
14 compressed fashion. It seems to be proceeding twice
15 as fast as other expedited proceedings before the NRC,
16 and that is seriously compromising the ability of the
17 intervenors to gather the evidence in an adequate
18 fashion.
19 Now one question that BREDL has raised is
20 what is the rush, because in every other aspect other
21 than this proceeding the U.S.-Russian MOX program is
22 proceeding at a glacial pace. For instance, there is
23 a failure to reach agreement on --
24 CHAIRMAN POWERS: To be honest with you,
25 we can't help you on that. I think we understand.

1 Let's move to the MOX.

2 DR. LYMAN: Okay. Well, I do think it is
3 important to keep the context in mind in this
4 proceeding, namely because the approval in this case
5 is going to set precedents for the future batch
6 loading, and also, like it or not, the U.S. is setting
7 an example for its Russian counterpart, and the NRC is
8 trying to instruct Russian regulators in how to
9 actually conduct its own proceeding. So we do want to
10 set a good example.

11 The ability of NNSA to ship plutonium to
12 France is not affected by NRC's decision. It is
13 simply a voluntary offer on the part of NRC to try to
14 comply with the request. So we do think we need to
15 take the time to do a thorough review. Next slide,
16 please.

17 Now I do want to make a few comments on
18 the security exemption request, because I think this
19 is probably the only opportunity in an open session
20 where we can get comments on the record. Nothing I
21 say is going to have any safeguards information in it.

22 The cover letter for the security
23 exemption as a rationale says that several
24 requirements in 10 CFR 73.45 and .46 are, quote,
25 "impractical and unnecessary to assure the security of

1 any MOX fuel assemblies."

2 If you look in the regulations, these

3 sections pertain to physical protection systems for

4 protecting formula quantities -- that is, Category 1

5 quantities -- of strategic special nuclear material

6 from the design basis threats of theft and sabotage,

7 and the details of the request are provided in seven

8 attachments, much of which NRC determined to have

9 safeguards information in it. Next slide, please.

10 One of the only public statements about

11 the substance of that comes from a Washington Post

12 article from last month where it stated that Duke

13 Power maintains that its security request is

14 reasonable, given the difficulty of diverting

15 plutonium contained the bulky fuel runs. Next slide,

16 please.

17 There is also some hint of the thinking

18 going on within NRC with regard to this application

19 from a publicly released review plan, which is

20 providing guidance to NRC staff who are reviewing

21 license applications involving storage of MOX fuel at

22 power reactors. This is a memo from Joe Shea to Gwen

23 Tracy, January 29, 2004. Next slide, please.

24 Some of the key pints of that publicly

25 released review plan is the staff's assessment that

1 MOX material is not attractive to potential
2 adversaries from a proliferation standpoint, basically
3 because it is big and bulky and dilute.
4 A large quantity of MOX fuel and elaborate
5 extraction process would be required to accumulate
6 enough material to fabricate and improvise a nuclear
7 device or weapon. Finally, that review points to an
8 exemption grant in 1989 from Category 1 security
9 requirements for fresh fuel stored at the Fort St.
10 Vrain gas cooled reactor. Next slide, please.
11 Some of the general observations I would
12 make about their plan is that this approach is
13 inconsistent with international standards and
14 judgments associated with the threat or the
15 attractiveness of plutonium contained in MOX fuel
16 assemblies.
17 For instance, there is no distinction
18 between plutonium in MOX fuel assemblies and
19 separating plutonium with regard to security with
20 regard to security, with regard to the international
21 convention on physical protection which the U.S. is
22 party, to the IAEA's guidance document on physical
23 protection, INFCIRC/225 (Rev. 4), the U.S. plutonium
24 disposition agreement which references INFCIRC/225
25 (Rev. 4) as a standard, and the National Academy of

1 Sciences original recommendation, which is that all
2 weapons using plutonium should be treated and
3 protected as if it were still in a nuclear weapon.
4 Also, the Fort St. Vrain security
5 exemption has little relevance to today's MOX
6 exemption request, putting aside the fact that it
7 dates from 1989, long before September 11th and the
8 security issues that have come forth since then. The
9 SNM content is much lower in the gas cooled reactor
10 elements than in the MOX fuel assemblies we are
11 talking about here, and the process for extracting HEU
12 from the gas cooled reactor fuel element is not nearly
13 as straightforward as that for separating plutonium
14 from MOX assembly.
15 So I just wanted to make those remarks.
16 I would urge the committee to look into this, and I
17 would be happy to come back and talk to you in a
18 closed session, if you believe it is warranted to look
19 more carefully at this other very important aspect of
20 this application. Next slide, please.
21 Now to get into the non-security related
22 contentions, the first reframed contention from the
23 Board deals with the fact that BREDL alleges that Duke
24 has failed to adequately account for differences in
25 MOX and LEU fuel behavior with regard to loss of

1 coolant accidents and other design basis accidents.

2 The issues that BREDL has pointed out

3 involve fuel related phenomena -- that is, MOX fuel

4 related phenomena that may affect compliance with the

5 ECCS criteria in 50.46 -- and also M5 cladding related

6 phenomena that may affect compliance with ECCS

7 criteria for the MOX LTAs. In that context, we are

8 thinking about any synergies between MOX fuel and M5

9 cladding that have not been adequately accounted for

10 in experiment.

11 This does lead us to the fundamental

12 problem that BREDL sees, which is that the

13 uncertainties due to gaps in the experimental database

14 from MOX under LOCA conditions is significant and

15 affects the ability of the NRC to conduct an adequate

16 review of this application.

17 I would point out the French safety

18 organization, IRSN, has proposed out a test at the

19 Phebus reactor, including a design basis LOCA test for

20 MOX fuel which might help to settle some of these

21 questions. Next slide, please.

22 CHAIRMAN POWERS: I am aware of the IRSN

23 proposing those tests. I am not aware of anyone

24 taking any action on that. I mean, people propose

25 tests all the time.

1 DR. LYMAN: Right. That is right, and I
2 don't know what -- Of course, I can't speak for NRC,
3 but there was some reluctance at the last presentation
4 I saw given by IRSN to NRC's supporting MOX fuel
5 tests, but we think that that is shortsighted.
6 CHAIRMAN POWERS: When I look at the
7 Board's discussion of the contentions, there seemed to
8 be some confusion between issues raised by IRSN on
9 high burn-up and issues raised on MOX.
10 DR. LYMAN: Well, there is no confusion in
11 my mind. The issue is for a given burn-up, how does
12 MOX and LEU compare. There may be a -- We know that,
13 because of the MOX fuel microstructure and the limited
14 experimental evidence there is, at relatively low
15 burn-ups compared to LEU, MOX microstructure mimics
16 that of higher burn-up LEU fuel.
17 So for a fixed burn-up, the concern is
18 that MOX fuel may appear more like higher burn-up LEU
19 fuel with regard to these effects.
20 Now whether -- how that translates to risk
21 across the entire core, especially in this high burn-
22 up fuel, is another issue. But our concern is really
23 the substitution of a MOX assembly -- of an LEU
24 assembly for a MOX assembly at the same burn-up.
25 DR. KRESS: My question was: Would that

1 concern be related to the future batch loadings or
2 just to the lead test assemblies?
3 DR. LYMAN: No. All these concerns are
4 amplified with regard to the batch loading, because if
5 you are replacing more LEU fuel with more MOX fuel, to
6 the extent that for a given burn-up MOX fuel is
7 inferior with regard to LOCA performance to LEU, then
8 that concern is going to be amplified.
9 Now one effect that we have identified
10 that NRC has not adequately taken into account is the
11 fuel relocation phenomena during a LOCA in which, as
12 a result of the clad ballooning in a design basis LOCA
13 and the fragmentation of high burn-up or MOX fuel,
14 fuel fragments will collapse, therefore increasing the
15 linear heat generation rate and potentially the ECCS
16 related parameters like peak cladding temperature.
17 Fuel relocation is not considered in the
18 Appendix K models at the present time, and we have
19 introduced -- and we have located some correspondence
20 of NRC that is questioning whether this was an
21 appropriate decision, especially given more recent
22 data and concern in Europe about fuel relocation and
23 its impact on these parameters.
24 According to IRSN, fuel relocation for LEU
25 fuel may increase peak cladding temperature by more

1 than 100 degrees Celsius, which is 180 degrees
2 Fahrenheit. The increase in peak cladding temperature
3 also results in increase in LOCA clad oxidation by
4 five to ten percent.
5 Our concern is that, by ignoring
6 relocation, to the extent that MOX fuel may be more
7 limiting than LEU in this case, that makes it even
8 less -- or even more non-conservative, and I point to
9 the lower margin for MOX generally because of the
10 typically higher temperatures for a fixed power level
11 and the fact that M5 cladding forms bigger balloons
12 because of the greater ductility in the Zircaloy. So
13 the synergy between M5 and MOX may be a problem that
14 has not been studied in integral tests. Next slide,
15 please.
16 CHAIRMAN POWERS: If I understand the IRSN
17 issues that they were addressing, those were issues of
18 relocation of fairly high burn-up material?
19 DR. LYMAN: Well, I think 48,000 megawatt
20 days per ton was where they first saw the effect in
21 LEU, but I'm not -- Lower than what was expected, in
22 that is considered high burn-up today, you know, above
23 62,000.
24 Again, one problem BREDL has is it doesn't
25 have access necessarily to a lot of the data

1 generating these international fora, particularly if
2 some of it is proprietary or concealed because of
3 various memoranda of understanding. So we don't --
4 All we are getting is little hints of the data that is
5 out there, and through the discovery process we are
6 trying to get more.
7 This Vu-graph, just taking the results of
8 Duke's large break LOCA calculation from the license
9 amendment request, peak cladding temperature was 2018
10 degrees Fahrenheit for MOX, while it was 1981 degrees
11 Fahrenheit for LEU for an assembly in the same
12 position.
13 Clearly, an increase of 180 degrees
14 Fahrenheit from relocation effects wouLD bring the PCT
15 to just under the regulatory PCT limit of 2200 degrees
16 Fahrenheit. So this, obviously, is a highly
17 significant effect in either case, but to the extent
18 that the margin for MOX is smaller, it is more of a
19 concern.
20 CHAIRMAN POWERS: But isn't this margin --
21 this limit, isn't it a real cliff, that if I am
22 2199.9, I'm okay? Isn't there margin built into the
23 whole concept there?
24 DR. LYMAN: Well, the 100 degrees Celsius
25 actually was a nominal figure, and actually one of the

1 documents that we obtained during discovery contains
2 additional IRSN calculations and which looks like 150
3 degrees Celsius for higher packing fractions is also
4 a possible increase due to this effect.
5 That's another uncertainty here, is any
6 difference in the packing fraction which affects the
7 peak cladding temperature increase due to relocation
8 between LEU and MOX at a fixed burn-up.
9 I would guess, to the extent that MOX
10 starts fragmenting at lower burn-ups than LEU and a
11 greater part of the fuel pellet is affected and
12 fragmented, that may mean the mean particle size -- or
13 fragment size is lower for MOX. But I don't have any
14 -- I haven't seen anything.
15 CHAIRMAN POWERS: What I am not aware of,
16 and maybe you can help me there, is a tendency for MOX
17 to fragment more extensively than LEU. In fact, one
18 would think that MOX would have inherently a low
19 fragmentation tendency, because crack tips get
20 blunted.
21 DR. LYMAN: Well, I'm just going by the
22 fact that the fission gas releases, you know, are
23 greater and you have at lower burn-ups more -- The
24 phenomena that were observed in the context of the
25 reactivity insertion experiments where there did seem

1 to be greater -- when MOX fuel rod failed at a lower
2 burn-up than LEU, there seemed to be greater
3 fragmentation and lower burn-up. But I don't -- There
4 is definitely a difference in the particle size
5 distribution. I don't know what it is, but it is
6 certainly a difference that should be considered.
7 It's possible that it is favorable.
8 CHAIRMAN POWERS: We can ask the staff to
9 help us on this fragmentation issue, because seems to
10 me that my limited experience with MOX is it shows
11 less tendency to break up in normal operations at a
12 given burn-up. But I can always be mistaken on those
13 things.
14 The fission gas release I understand.
15 It's not connected with fragmentation at all. It has
16 to do with the microstructure.
17 DR. LYMAN: Well, again, these are
18 uncertainties that need to be addressed. Next slide.
19 Now as far as the M5 cladding issues goes,
20 in addition to any synergy between M5 and MOX, it
21 hasn't been well studied. The issue of the tendency
22 of the zirconium-niobium alloys to embrittlement
23 appears to be, I think, a little less clear, and it
24 may have been a couple of years ago, and the
25 dependence on the initial surface treatment, polishing

1 versus etching, I think, raises questions that need
2 further examination.
3 I would point to the experiment that was
4 done at Argonne that was disclosed in a letter dated
5 May 5, 2003, which only appeared on ADAMS within the
6 last few weeks, where it was remarked that an Argonne
7 oxidation test on etched M5 samples showed a potential
8 similarity to the oxide characteristics of alloy E-
9 110. This is a letter from framatome to NRC that
10 would seem to be quite concerned about the way the
11 outcome of that test looked.
12 CHAIRMAN POWERS: Or words associated with
13 those tests: One struggles to understand what a
14 potential similarity means. Not your fault. It's the
15 words the author used.
16 DR. LYMAN: Well, that is all we've got,
17 but judging from the publicly available information,
18 it seems that there is quite some concern on
19 Framatome's part that this experiment was done. Since
20 etching is not the initial surface treatment that is
21 carried out for M5, it is not clear why there is that
22 concern, but I think until this phenomenon is fully
23 understood, there are going to be questions regarding
24 the stability of M5 with regard to differences in
25 production conditions, and especially the changes in

1 irradiation, corrosion, hydrogen uptake that NRC hopes
2 to address through tests on irradiated high burn-up M5
3 fuel at Argonne.
4 CHAIRMAN POWERS: In your researches on
5 M5, have you been able to look at what the experiences
6 are in Europe with the use of M5 ?
7 DR. LYMAN: Well, again the normal
8 operation, which was what supported the original
9 request for M5 cladding approval in this country, that
10 is well documented. But what isn't so well documented
11 is a full understanding of the relationship between
12 surface condition and its behavior in embrittlement
13 after oxidation.
14 The Framatome -- After the E-110 issue
15 first arose, Framatome quickly provided the results of
16 ductility testing that showed that M5 wasn't too
17 different from Zircaloy and did not look like E-110,
18 did not experience this nodular oxidation that seems
19 to be the problem. But to the extent that, again, the
20 phenomenon is not fully understood, I think we need to
21 have tests on high burn-up irradiated M5 integral LOCA
22 tests just to confirm that the surface changes during
23 irradiation don't lead to any surprises.
24 You know, we don't want surprises to occur
25 in the core of a reactor. You know, that is the last

1 place you want a surprise to occur, and the fact that
2 M5 turned out not to share E-110's propensity to
3 embrittlement at a lower oxidation level seems to be
4 a coincidence, as far as I can tell, and it's a lucky
5 coincidence, but to the extent it is not understood,
6 it is still a coincidence.
7 CHAIRMAN POWERS: I guess I am perplexed
8 a little bit when you say it is coincidence. I mean
9 it's the behavior of the material or you are you
10 suggesting that there is a stochasticity here?
11 DR. LYMAN: Well, no. I'm just suggesting
12 that the ring compression tests which showed that it
13 revealed this behavior in E-110 which wasn't, I guess,
14 seen through simple strength tests or quench tests,
15 that those tests were not done in M5. M5 was
16 originally qualified in this country based only on
17 impact tests after Quench, and the ring compression
18 tests were done after the issue associated with E-110
19 came up.
20 So to the extent that those tests sampled
21 different material characteristics, that wasn't known
22 before. If my recollection of the history of this is
23 incorrect, I hope that staff will correct me. That
24 is the way it looked on the outside. Next slide.
25 BREDL's contention 2, the reframed

1 contention by the Board, deals with differences in MOX
2 and LEU with respect to the releases during what are
3 called core disruptive accidents, which encompass any
4 core melt from design basis LOCAs and beyond.
5 I don't see any need to sit here and tell
6 you guys about the issues associated with
7 uncertainties in experimental databases for core melts
8 and severe accidents with regard to MOX fuel, but I
9 would just remind you of the expert panel report which
10 at least two of you sat on, which remarked that there
11 may be a different degradation behavior of MOX during
12 core melt that may lead to different release
13 characteristics.
14 The few tests that have been conducted
15 seem to indicate some radionuclides have enhanced
16 release rates for MOX, and the current regulatory
17 source term may underestimate release fractions of
18 groups like tellurium and ruthenium, ruthenium in
19 particular with regard to any air oxidation occurring
20 late in vessel phase, and because both those isotopes
21 are typically greater -- have greater inventories in
22 MOX because of the different fission product spectrum
23 for MOX fission that, to the extent those source terms
24 aren't adequately taken into account, that is another
25 potential non-conservatism with respect to MOX source

1 terms.

2 Again, the -- Sorry.

3 CHAIRMAN POWERS: We are looking at LTAs

4 here, so you could have relatively radically different

5 source terms, and it wouldn't really affect things at

6 all, would it?

7 DR. LYMAN: Well, it will affect things

8 more than -- I mean, there will be a difference.

9 Duke's own -- Duke referred to Department of Energy's

10 original EIS to point out that there was a couple of

11 percent at most difference in release in population

12 dose or various dose related characteristics

13 associated with that release, associated with the

14 difference in source terms.

15 That didn't take into account -- That only

16 accounted for differences in inventory. This just

17 hasn't been -- The calculation hasn't been done yet

18 with the uncertainties in the source terms that are

19 important for the differences in MOX and LEU taken

20 into account.

21 What is significant, what is insignificant

22 is a judgment call. There is limited regulatory

23 guidance, and that is not something we have taken a

24 position on this time, but we think it has to be

25 properly accounted for before you can make a

1 determination whether it is significant or
2 insignificant. And that simply hasn't been done yet.
3 To the extent that the uncertainties are
4 large because the experimental database is sparse,
5 that has to influence the ability of NRC to make a
6 judgment call as to whether there is enough
7 information to conclude that there is insignificant
8 risk increase associated with this amendment.
9 Once again, I point out that IRSN has
10 proposed doing source terms as to MOX fuel and severe
11 accident conditions, and again we think that such
12 experiments would be well worth the cost to resolve
13 some of these issues. Next slide.
14 So to conclude, we believe that more
15 research is needed to reduce the uncertainties in M5
16 cladding and MOX fuel performance to support this
17 application. We note that there may be LOCA tests
18 with a rated M5 clad fuel with LEU fuel.
19 We note there is fuel relocation tests
20 going on at Halden, and I don't have the details how
21 that's come out, and we note that IRSN has proposed an
22 additional test series.
23 We think all of these are necessary to
24 begin understanding and reducing the experimental
25 uncertainties associated with MOX.

1 With that, I will conclude.

2 CHAIRMAN POWERS: I think you have raised

3 three major technical issues here not associated with

4 security that we need to consider as we go through

5 here. By my count, you've raised the issue of

6 relocation and fragmentation. You've raised the issue

7 of the cladding, and you have raised the issue of

8 source term here. Is that a roughly correct synopsis?

9 DR. LYMAN: Yes, that is. With regard to

10 the MOX fragmentation issue, again it is something

11 that just needs to be better studied, because there

12 will be a difference. If it is beneficial, it is

13 beneficial, but I think it needs to be taken into

14 account.

15 CHAIRMAN POWERS: Now my understanding is

16 that MOX fuel, at least in the pellet form, have been

17 taken up to radiation levels as high as 100 gigawatt

18 days per ton. Is that correct?

19 DR. LYMAN: In light water reactors?

20 CHAIRMAN POWERS: No, in test reactors.

21 DR. LYMAN: I'm not aware. Certainly, in

22 the fast spectrum reactors those burn-ups were

23 achieved, but there is no comparison. I think the

24 neutron spectrum differences are significantly great

25 and the production methods for those were considerably

1 different from those today, but I don't how much
2 relevance fast reactor fuel performs as of current --
3 on light water reactors.
4 CHAIRMAN POWERS: Any other questions you
5 want to pose to Mr. Lyman?
6 DR. LEITCH: Yes. I had just a question
7 of understanding. Both contentions really say that
8 Duke has failed to adequately account for differences
9 between the MOX and the LEU fuel. These differences
10 are both known differences and recent information on
11 possible differences, and one relates to primarily
12 LOCA and the other primarily to releases.
13 Have you discussed the recent information
14 on possible differences? Is that basically what -- I
15 mean, I understand the known differences, but what is
16 the issue about recent information on possible
17 differences?
18 DR. LYMAN: Yes. I think what the Board
19 was trying to get at -- what we have discussed now is
20 largely in that category. Known differences, I think,
21 would refer more to issues like in Duke's application
22 and on the environmental report it simply referenced
23 a Department of Energy calculation from a few years
24 ago that was based on, let's say, an inventory
25 generation radionuclide inventory that I don't think

1 was correct, for example.

2 So I think the emphasis really is on

3 differences that are -- Obviously, these are well

4 known, but not well understood. So that's probably a

5 better way to characterize, I think, where the heart

6 of the matter lies.

7 DR. LEITCH: But my question basically:

8 Is there other recent information on possible

9 differences other than what you have discussed here or

10 you've told us?

11 DR. LYMAN: No. These were the chief

12 issues, stemming primarily from a presentation that

13 IRSN gave to NRC in October, which crystallized in my

14 mind how much isn't known about MOX fuel performance.

15 Again, a lot of these are issues that have been kicked

16 around a long time, but simply not taken seriously

17 enough to call for an effort to resolve them fully in

18 an experimental setting until now.

19 DR. KRESS: I am still hung up on whether

20 BREDL was concerned with potential risk impacts of the

21 two percent loading of MOX in Catawba or are they

22 really concerned that this is a precedent for much

23 higher loadings in a batch reactor later on.

24 DR. LYMAN: Well, in the context of this

25 proceeding which deals specifically with the LTAs, our

1 point is simply you can't begin to make a
2 determination of what is significant or not until you
3 have a good number, and we don't think they have a
4 good number yet.
5 Then you can debate about whether that is
6 a significant impact. Again, that is a relative term
7 which has something to do with risk-benefit. So it's
8 not directly comparable to other issues where there
9 are risk increases associated with license amendment.
10 I think each one has to be judged on its own.
11 Putting that aside, though, in the larger
12 picture BREDL is, of course, concerned with batch
13 loading and nailing down these uncertainties so that
14 there is a proper counting of the additional risks
15 associated with that application, which is coming or
16 expected to come next year.
17 Of course, the sooner there is a
18 commitment to resolving some of these issues, the
19 better and the less potential delay there will be in
20 a challenge to that amendment.
21 DR. KRESS: Thank you.
22 CHAIRMAN POWERS: Any other questions?
23 Thank you, Ed. It is always useful to hear from you.
24 You have raised some issues for us, and hopefully, we
25 will get those clarified over the course of the day.

1 DR. LYMAN: Thank you.

2 CHAIRMAN POWERS: At this point I will
3 turn to Mr. Nesbit to discuss the MOX fuel lead
4 assembly program.

5 MR. NESBIT: Thank you. In the interest
6 of time, I am going to dispense with the majority of
7 my presentation and simply make a few points. I would
8 ask you to go to Slide 6. That will be the first one
9 that I will actually talk from.

10 These points that I make are not at the
11 current time related directly to that slide, but I
12 will point out the MOX fuel lead assembly program,
13 which we are discussing today, is a critical part of
14 the overall program to dispose of surplus weapons
15 plutonium.

16 It needs to happen if the program is going
17 to go forward. Due to factors, including the
18 availability of a site for fabrication of weapons
19 grade MOX fuel lead assemblies, it needs to happen
20 now.

21 Duke and Framatome have engaged in a
22 substantial dialogue with the NRC over the past years
23 related to MOX fuel use, culminating in a number of
24 topical reports and the license amendment request
25 itself and responses to requests for additional

1 information which grew out of the NRC review. And as
2 Bob Martin pointed out, that culminated in the issuing
3 of a safety evaluation earlier this month.
4 On Slide 6, which is up there on the
5 screen, I summarize some of the technical work that
6 has been presented to the NRC. Duke has provided NRC
7 with topical reports related to the thermal-hydraulic
8 performance of the MOX fuel and nuclear analysis.
9 AREVA or Framatome has provided topical
10 reports related to fuel mechanical performance of MOX
11 fuel. That is COPERNIC, the fuel assembly design that
12 is going to be used, and a MOX fuel design topical
13 report that addresses more specifically MOX fuel
14 related issues. And of course, we have the license
15 amendment request and associated exemption requests.
16 There is a security plan change and
17 exemption request that has been provided to the NRC,
18 and that is not the subject of this meeting, and I am
19 not going to talk about that any further.
20 The DOE has requested -- applied to the
21 NRC for an export license. That application is
22 pending, as are requests for certification for
23 transportation packages associated with plutonium
24 oxide powder and MOX fuel lead assemblies.
25 There's a lot of things in front of the

1 NRC, but we are going to concentrate today on our lead
2 assembly license amendment request.
3 You have heard from Ed Lyman about some of
4 his concerns. We have addressed in our application
5 and related materials the difference between mixed
6 oxide fuel and low enriched uranium fuel to the extent
7 that they could possibly affect the safety case for
8 using the fuel at Catawba, and we are going to talk
9 about that in subsequent presentations.
10 I would characterize the BREDL issues as
11 threshing around between hearsay of presentations and
12 letters here and letters there to try to come up with
13 some issue that could be blown out of proportion, but
14 in the context of this application for four MOX fuel
15 lead assemblies, we have presented a robust safety
16 case.
17 CHAIRMAN POWERS: If I look at look at the
18 heart of the issues that Mr. Lyman has just addressed
19 for us, it seems to me that one of his contentions --
20 the central contention he makes is that there is just
21 not a lot of experimental data on the MOX fuel. I
22 mean, is that a fair characterization?
23 MR. NESBIT: That is probably a fair
24 characterization of his contention. I wouldn't agree
25 with it.

1 CHAIRMAN POWERS: Okay. So you will help
2 us to understand what we know here?
3 MR. NESBIT: And I'm not going to address
4 that right now, but in subsequent presentations, we
5 will.
6 CHAIRMAN POWERS: Sure.
7 MR. NESBIT: The presentations that follow
8 will be by Patrick Blanpain of Framatome in France who
9 will talk about the MOX fuel experience base, and also
10 current and future plans for MOX fuel use. I think
11 some of the members of this subcommittee have heard
12 from Mr. Blanpain before.
13 George Meyer from Framatome in the U.S.
14 will talk about the fuel assembly design. Jim Eller
15 from Duke Power will talk about the nuclear design
16 aspects and our plans for core loading of mixed oxide
17 fuel in lead assemblies, and I will wrap up and talk
18 about the safety and environmental analyses and
19 evaluations that we have performed.
20 There is way too much information in what
21 we have submitted to cover here, and we are not going
22 to try. I will note --
23 CHAIRMAN POWERS: You have found a good
24 occupation for my evenings and weekends. My wife
25 thanks you. She hasn't seen her kitchen table now in

1 several weeks.

2 MR. NESBIT: You're certainly welcome.

3 One thing that we are not going to talk

4 about further except in a limited extent is the

5 question of the Westinghouse NGF lead test assemblies

6 that, based on current plans, would be co-resident

7 with the MOX fuel as it would be loaded in the spring

8 of 2005 at Catawba.

9 In Mr. Eller's presentation, he will show

10 the locations of -- planned locations of the fuel.

11 The details of the NGF fuel assembly are proprietary

12 to Westinghouse, and I can't talk about them in this

13 meeting, in this context. There will be a meeting on

14 Friday that Bob alluded to at which some of that

15 information can be shared, although that is also not

16 a proprietary meeting.

17 I will characterize the Westinghouse NGF

18 fuel assemblies as fundamentally similar to the

19 current co-resident RFA fuel assemblies. It is a

20 little different, but to the extent that there are

21 differences, those differences, if they had any effect

22 on mixed oxide fuel lead assemblies, which they would,

23 the differences would actually be beneficial to the

24 MOX lead assemblies.

25 We have some people in addition to the

1 presenters who are here. If you have questions that
2 get into specific areas of technical detail, we will
3 do our best to respond to them.
4 I'd like to make another point, and then
5 I will turn it over to Patrick. What you have heard
6 from BREDL is basically an argument that, in order to
7 have a MOX fuel lead assembly program, you need
8 perfect certainty about everything that is going to
9 happen.
10 Well, I think that is inconsistent with
11 the history of fuel development in the United States
12 in nuclear power, and I think it would be
13 fundamentally a chilling approach to take to say that,
14 before we can run a lead assembly program in a
15 reactor, we have to know everything.
16 That is not the NRC's regulatory charge.
17 The standard NRC uses is reasonable assurance, and we
18 feel we have met that standard.
19 So now I would like to turn it over to
20 Patrick Blanpain, and he will discuss his experience
21 and Framatome's experience with MOX fuel use in
22 Europe.
23 MR. BLANPAIN: Thank you. The objective
24 of my presentation is to show you the fabrication and
25 the additional experiments of Framatome in Europe, and

1 the main part of my presentation will be an overview
2 of the reactor performance of the MOX fuel.
3 I start with some facts. Since the first
4 commercial reloads in 1972 in Germany and in 1987 in
5 France -- of course, it was in one reactor --
6 plutonium recycling as performed in the form of MOX
7 fuel has reached an industrial maturity.
8 The production capacity today in Europe
9 and used by Framatome ANP is about 150 Thm/year using
10 the MIMAS process in the French Melox and in the
11 Belgian Belgonucleaire plants.
12 More than 2400 fuel assemblies have been
13 delivered by Framatome ANP/France to 20 French, two
14 Belgian and four German pressurized water reactors,
15 and more than 1300 fuel assemblies have been delivered
16 by Framatome Germany to 11 German and three Swiss PWRs
17 and BWRs. Next slide.
18 I will now recap about the MOX fuel
19 fabrication. So we start with UO_2 and PuO_2 powder.
20 That primary blend is mixed and micronized with some
21 recycled scraps, and then that primary blend is
22 sieved. We had lubricant of pore former, and feed UO_2
23 powder into that original to reach the final blend,
24 and then that final blend is pressed, sintered,
25 ground, inspected and loaded in the fuel rods like in

1 the UO_2 process. Next slide.

2 Now the primary blend: We are starting

3 with the UO_2 powder, with the PuO_2 lots, and they are

4 mixed and then ground, micronized, which is the

5 primary blend, and the principal compound in that

6 primary blend is between 20 and 30 per the UO_2. I am

7 showing that primary mixing. The recycled scraps from

8 the fabrication are this. Next slide.

9 Then that primary blend after sieving is

10 mixed with fresh UO_2 powder to reach the final

11 plutonium content. Next slide.

12 Then at that final blend, the different

13 lots of secondary blends with lubricant, then mixed,

14 pressed, sintered and controlled as UO_2 fuel. Next

15 slide.

16 Okay. That is the results. It's the

17 microstructure of that MOX fuel using the MIMAS

18 process. On the top of the slide it is electronic

19 image obtained by a electronic probe microanalysis,

20 but the top image is showing -- Showing white, the

21 plutonium rich particles. That's in white, and in

22 black is the UO_2 fuel matrix.

23 After image analysis, now going to the

24 back of the image, we can see in red and yellow the

25 plutonium, in blue the uranium that is on the right

scale of the plutonium content from UO_2, 50 percent. So we can see that most of the concentration is around 20 percent in the master blend.

Then if we increase the contrast, we can see in red the plutonium rich particles with an enrichment -- plutonium enrichment higher than 20-25 percent of plutonium, a blue phase which is almost fuel UO_2, and a green phase called the coating phase between the UO_2 grains. We have a plutonium content between 2 and 5 or 10 percent. Next slide, please.

Then we can construct a calculated analysis if that plutonium distribution. So that graph on the y axis -- or x axis, sorry, there is a cumulative plutonium -- the plutonium content. And on the y axis the size of the plutonium rich particles.

We can see, for example, on the left that in the MIMAS MOX fuel we have only 25 percent of the total plutonium in the plutonium rich particles. For example, there is a 10 percent of the total plutonium is included in the large particle, larger than 100 microns. Also that means that 75 percent of the total plutonium is in the coating phases or in the UO_2 phase. Next slide, please.

That is another representation of the microanalysis. It is an analysis crossing a pellet

1 diameter, and I have presented here a series of large
2 plutonium agglomerates, but it is important to note
3 that the maximum plutonium content in those
4 agglomerates is around, in that case, 27 percent. It
5 is the red line. It is the plutonium content of the
6 primary blend.
7 It is important to note that there is no
8 very high plutonium content in those particles, higher
9 than the primary blend content. Next, please.
10 Now the different fuel designs used in
11 Europe for the MOX fuel. So the MOX fuel is used in
12 light water reactors up to power of 1300 electric, and
13 it is different fuel assembly we can design, under 14
14 by 14, for example, to the 18 by 18.
15 In Europe we are using different design
16 and type of fuel management. The plutonium content
17 used is 75 percent with an average assembly. It just
18 goes from U^{235} enrichment up to 4.3 percent, and really
19 one-third and one-fourth core loadings can use it,
20 usually NEL, but in some cases, for example --
21 Belgium, for example -- they are using up to 18 month
22 cycles.
23 The core fraction is usually 30 percent,
24 but 50 percent is licensed in Germany for boiling
25 water reactors, and 38 percent are used.

1 For the UO_2 matrix, depleted uranium or --
2 uranium are used. It is normally depleted today. The
3 current discharged boiler fuel assemblies is between
4 45 and 50 GWd/tHM and up to 60 for individual fuel
5 assemblies.
6 It is important to know that the MOX can
7 operate in load follow mode since more than 10 years
8 in France, and also the failure rate -- We have the
9 same failure rate as uranium fuel, an that no rod ever
10 failed for MOX specific reasons. That means that, due
11 to the correct fabrication of the MOX fabrications.
12 So typically, the failure rate is less
13 than one rod there, 100 in 1,000 rods. Next, please.
14 CHAIRMAN POWERS: Just doing a quick
15 calculation, that suggests you had a couple of rods
16 fail? You've had two rods fail? Is that roughly
17 correct?
18 MR. NESBIT: There is information in the
19 MOX fuel design report about the MOX fuel failures in
20 one of the appendices. It has been more than two
21 rods.
22 DR. BONACA: On the recycle rate, license,
23 what are the limits, the amount of MOX fuel you
24 introduce in the core?
25 The question I had was on the recycle

1 rate. You said that 50 percent is licensed in
2 Germany?
3 MR. BLANPAIN: Yes.
4 DR. BONACA: And 38 percent is used. What
5 is the basis for the 50 percent?
6 MR. BLANPAIN: I do not exactly -- What is
7 the basis of -- Maybe it is the basis of the parameter
8 of the void fraction in the core that limits the use
9 of MOX fuel or the fraction of MOX in the core.
10 DR. BONACA: Okay. So that is the basis
11 there.
12 MR. BLANPAIN: Yes. But those are -- In
13 France, for example, the 30 percent is also -- to go
14 back to -- we have a UO_2 fuel. So that is to put two
15 more MOX in one core to get a high visibility, easy.
16 So the next slide shows the irradiation
17 experience in Europe by Framatome France. It is
18 mainly -- It is in the pressurized water reactors at
19 mainly 17 by 17, three reactors in France.
20 You can see mainly two peaks. The first
21 one to the left is the French experience with the
22 discharge burnup for up around 37. It is assembly
23 burnup, and to the right is the discharge burnup in
24 Belgium, in Germany, which are higher. The discharge
25 burnup is around 55 to -- 45 to 50. Next one.

1 I have got the same representation of the
2 fuel fabricated by Framatome Germany, ex-Siemens, and
3 showing that the discharge burnup is quite higher in
4 Germany and in Switzerland, and that also higher --
5 very high burnup fuel have been discharged from --
6 higher than 55. Next one, please.
7 So what about fuel design and then
8 performance? So usually the mechanical design of the
9 fuel assembly structure is identical for MOX and for
10 UO_2 fuels. It is the materials used as well as the
11 skeleton of the assembly.
12 As for UO_2, we need a reliable prediction
13 of the thermo-mechanical behavior of the MOX fuel
14 rods. That should be obtained through an adequate
15 description of the MOX-specific properties as for UO_2,
16 and that means the design models and the codes to be
17 continuously verified by comparison with measurements
18 to obtain finally the same level of accuracy as for
19 uranium fuel, and show you that now. Next slide.
20 This is an example of the MOX properties.
21 It's easy to see. That shows the thermal conductivity
22 of the MOX fuel compared to UO_2, temperature. The
23 graph shows a very small difference, a difference of
24 the picture of MOX fuel with about 5 percent of PuO_2.
25 It is around a 5 percent difference on thermal

1 conductivity.

2 The next one shows the specific heat of

3 the MOX fuel compared to UO_2. On the x axis here is

4 the specific heat, on the y axis the temperature. The

5 red star is specific heat of UO_2 with -- and the

6 different points result from different experience

7 coming from the literature, and but addressing MOX

8 fuel with 20 percent of PuO_2.

9 You can see that sometime -- most of the

10 time you have conservative, and for the MOX fuel with

11 low plutonium content that we use in light water

12 reactors, it is recommended to use the PuO_2

13 correlation.

14 CHAIRMAN POWERS: So you say that that is

15 -- using the UO_2 correlation is conservative.

16 MR. BLANPAIN: This?

17 CHAIRMAN POWERS: Is conservative?

18 MR. BLANPAIN: It is mostly conservative,

19 yes.

20 CHAIRMAN POWERS: But, I mean, the

21 specifics of the heat seems higher, and it seems to me

22 that the conservative position would be to use a lower

23 specific heat.

24 MR. BLANPAIN: No. There is no -- We have

25 data from MOX fuel is high plutonium content at 220,

1 and they are using 5 percent plutonium content. Also,
2 it is not seen here, but for very low plutonium
3 content we have seen a decrease -- to some extent, a
4 decrease in specific heat.
5 So it is the reason why we are using the
6 UO_2 correlation, which is conservative compared with
7 the UO_2 experiments.
8 CHAIRMAN POWERS: Well, I guess I am a
9 little puzzled, because I mean, for a given heat
10 input, the temperature you arrive is lower.
11 MR. NESBIT: I guess, if I can interject,
12 it is sometimes dangerous to make a statement that so
13 and so is conservative or not conservative, because it
14 depends on the application that you are using it for.
15 CHAIRMAN POWERS: Absolutely.
16 MR. NESBIT: It may be conservative for
17 one and not for another. I think the fundamental
18 point that Patrick is trying to make is that, for the
19 kind of plutonium concentrations we are looking at for
20 our MOX fuel, which is less than five percent
21 plutonium in the pins, the specific heat is virtually
22 indistinguishable between MOX and LEU, and using the
23 LEU value is appropriate.
24 CHAIRMAN POWERS: Let me also comment
25 that, if I compare your specific heat curve here for

1 UO_2 against those in recent review articles on UO_2, I
2 fail to see a discontinuity up above about 2600
3 Kelvin. It has been variously attributed to second
4 order phase transitions and the like.
5 I wonder why that is not reflected there.
6 You don't see it when you make the measurements?
7 MR. NESBIT: I don't think we've got an
8 answer for you right here.
9 CHAIRMAN POWERS: Well, I think for some
10 time, since at least 1980, there's been recognition
11 that something funny happens in UO_2 in the vicinity of
12 about 2600. Your initial reaction to it is we've had
13 the onset of a disorder in the lattice, and it doesn't
14 take long to figure out the discontinuity is way too
15 big to be that, and it just didn't show up in these
16 curves.
17 There has been a recent review article --
18 I probably cannot pull out the citation in my head,
19 but of course, the most famous stuff is the stuff that
20 was done at Argonne back in the Eighties in their
21 review of uranium dioxide from a physical properties.
22 But it has been reiterated.
23 I mean, people have made these
24 measurements a lot, and they see this discontinuity,
25 and you have a smooth transition looking like probably

1 the onset of charge carrier effects here. But I don't
2 know. Please go ahead.
3 DR. LEITCH: On that slide I don't
4 understand what the X=2-O/M is. What is that? What
5 is O and M in that?
6 MR. BLANPAIN: That is a deviation from
7 stoichiometry. It is a deviation from the
8 stoichiometry.
9 DR. LEITCH: Oh, okay.
10 CHAIRMAN POWERS: Yes, the plutonium tends
11 to -- on these systems, and so you get
12 hyperstoichiometric fuel pretty easily. Are you
13 planning on touching on the oxygen potential changes
14 as a function of temperature and plutonium content?
15 It seems to me that that is the issue when you talk
16 about internal oxidation of the clad, is what the
17 change in the oxygen potential is for the
18 hyperstoichiometric material here.
19 MR. BLANPAIN: The MOX fuel?
20 CHAIRMAN POWERS: Yes.
21 MR. BLANPAIN: I'm not sure -- the
22 tendency is to become stoichiometric, because I think
23 slightly hyperstoichiometric and going to
24 stoichiometric.
25 CHAIRMAN POWERS: Yes. That is because of

1 the fission release of oxygen. What I'm interested in
2 is how the oxygen potential of the fuel changes over
3 the course of the irradiation as a function of Pu
4 content.
5 MR. BLANPAIN: We can make that later,
6 because of all the cladding oxidation.
7 Okay, the next one, please. It's a
8 graphic showing the thermal expansion of UO_2 compared
9 to MOX fuel. It says there is no effect of the
10 addition of PuO_2 thermal expansion.
11 Now some examples of the two graphs
12 showing --
13 CHAIRMAN POWERS: On this slide you have
14 -- In your legend here you have PuO2 with a bracket 1,
15 UO_2 with a bracket 1, PuO_2 with a bracket 2. I'm just
16 guessing that those are references?
17 MR. BLANPAIN: Yes, those are references.
18 CHAIRMAN POWERS: Are those references
19 provided? I would appreciate it if you would provide
20 those.
21 MR. BLANPAIN: Okay. So as an example
22 that we are looking at the physical properties of the
23 MOX fuel on the irradiated materials also during
24 irradiation. That is an example of the measurement of
25 the fuel central line temperature, first on the un-

1 irradiated fuel and measured during irradiation with
2 the central thermocouples on small -- in experimental
3 reactors.
4 There is fuel central temperature on the
5 x axis, and the heat generation on the y axis. That
6 shows small difference between the temperature of the
7 MOX and UO_2. Typically, the temperature of -- the
8 temperature of the MOX fuel is 15 degrees -- 50
9 degrees higher than UO_2, 200 per centimeter. The
10 next, please.
11 CHAIRMAN POWERS: Why?
12 MR. BLANPAIN: Thermal conductivity.
13 CHAIRMAN POWERS: The thermal conductivity
14 is minusculely different. The density can't be wildly
15 different. So it all has to be the -- It has to be in
16 the specific heat. I mean, it has to be a difference
17 in thermal diffusivity. Right?
18 MR. BLANPAIN: The thermal diffusivity.
19 CHAIRMAN POWERS: And it can't be the
20 thermal conductivity. It can't be the density. So it
21 must be the specific heat. I mean, that's the only
22 thing left to you. Right? I mean, the thermal
23 conductivity you showed us is --
24 MR. BLANPAIN: Diffusivity.
25 CHAIRMAN POWERS: Yes, it has to be a

1 difference in thermal diffusivity. So it has to be in
2 the specific heat. That is the only thing open to us,
3 unless the thermal conductivity changes wildly in the
4 course of the irradiation, but these are modest
5 irradiations.
6 MR. BLANPAIN: The conductivity curve,
7 because this is what is used in the computer codes.
8 A feature to be predicted is the fission
9 gas release, because it depends mainly on temperature.
10 It is taken against measurements made by the COPERNIC
11 code and the calculation on the x axis and the
12 measurement on the y axis, and I represented here the
13 database of -- and comparing the MOX fuel -- The MOX
14 fuel is in red. No, in black. Okay, in black,
15 compared to the UO_2 fuel in blue and red.
16 That is to show that there is no bias
17 brought by the MOX fuel. The clarity of the
18 prediction is very similar to the other fuels. That's
19 the message.
20 DR. KRESS: Can we go back to the previous
21 slide. I'm not sure I understood the discussion.
22 These are temperature center line differences at
23 steady state. Right? Stead state only involves
24 thermal conductivity. I still don't understand this
25 difference. These are steady state results.

1 MR. BLANPAIN: The steady state?

2 DR. KRESS: Yes. You are not in a

3 transient.

4 MR. BLANPAIN: Yes, but --

5 DR. KRESS: The thermal conductivity is

6 the only -- and the heat generated is the only

7 difference in distribution, is the only things that

8 enter into the steady state. So I don't understand

9 the answers you got.

10 MR. BLANPAIN: Yes, but you need to know

11 the -- to verify your calculation in your normal

12 operation. That is the reason of that experiment.

13 That is what normal operation causes in Phase 1 and

14 Phase 2 situations, but the answer to check the --

15 accident condition is presented here.

16 DR. KRESS: Certainly. That leads me to

17 my question. This must be due to the different power

18 generation distribution. It can't be due to the

19 diffusivity. It must be a power difference. Your

20 thermal conductivity is almost the same. If I were to

21 calculate this, the only thing that enters into that

22 is power generation rate and the thermal conductivity.

23 MR. NESBIT: I think we would agree with

24 you, that the two factors are the pellet radial power

25 profile and the thermal conductivity.

1 DR. KRESS: I would buy that answer
2 better. I didn't understand the previous one.
3 MR. BLANPAIN: Yes, but of course, those
4 type of -- kind of experiments, because we have also
5 done it for high burnup fuel and so on, and of course,
6 the difference in temperature between MOX and UO_2 is
7 not only due to the thermal conductivity, called the
8 power radial profile difference. We know that it is
9 taken into account in the computer codes.
10 DR. RANSOM: Were these cladded?
11 MR. BLANPAIN: Yes.
12 DR. RANSOM: So what about the gap
13 conductance? It would enter into that, too.
14 MR. BLANPAIN: Well, we have performed
15 experiments such as this one. We are using exactly
16 the same pellet geometry and the same enrichments, the
17 same cladding material, the same gaps and so on. We
18 know that is not evident to compare that. We need
19 such experiments to verify the predictions.
20 DR. RANSOM: Do you have any idea of the
21 uncertainty in this measurement due to dimensional
22 tolerances --
23 MR. BLANPAIN: Usually, the experiments --
24 People perform hundreds of experiments with central
25 thermocouples to benchmark the temperature prediction

of the fuel, but it is around -- what is used usually is between 5 and 10 percent on the final uncertainty, knowing that the highest uncertainty is brought by the uncertainty of the power during the experiment and not due to the instrumentation.

DR. RANSOM: Well, the 5 to 10 percent would almost account for the difference, if this is just one case.

MR. BLANPAIN: Yes, it is one case, but we have many cases. It is described in the COPERNIC manual, how we manage those datapoints. It is essentially --

DR. RANSOM: This difference may be insignificant. Is that correct?

MR. BLANPAIN: It is exactly the same for the other fuels, for UO_2, for example. There is no new bias brought by the MOX fuel.

So continuing with the feedback experience -- many come from the surveillance program where we build rods and examined those rods in hot cells, and also coming from analytical experiments.

So about more than 100 commercial fuel rods from German and French reactors were examined in hot cells up to high burnups, and also we participated in a lot of national and international programs for

1 analytical irradiations. These are international
2 programs like Halden, for example.
3 We have performed power ramping with the
4 MOX fuel and with instrumentation to assess the PCI
5 properties of the MOX fuel, the fission gas release,
6 the in-pile densification and so on. Those
7 experiments were largely published in the open
8 literature.
9 And what was the main reasons of those
10 programs? The next, please. We have very similar
11 behavior of the MOX and UO_2 fuels concerning the rod
12 growth. There is no effect on the MOX pellet, in
13 connection of the MOX pellet and the cladding, model
14 cladding diameteral deformation, the same for MOX and
15 UO_2 fuel; concerning the cladding waterside corrosion
16 -- I shall show you an example; model pellet solid
17 swelling -- I also show you an example; the zirconium
18 internal layer. So the oxidation of the internal
19 layer of the cladding is the same as on UO_2, and we
20 have seen at high burnup that the mechanical
21 interaction between the -- or the chemical interaction
22 between the pellet and the cladding is similar.
23 As far as the fission product and
24 activity, release of the failed rod are similar for
25 MOX and the UO_2 fuel. So it is difficult to determine

1 leakage from UO_2 fuel. That could be, but it is not
2 so easy.
3 WE have seen a somewhat higher fission gas
4 release in MOX fuel than for UO_2 fuel, mainly at high
5 burnup. That could lead to higher fuel rod internal
6 pressure. Also, the MOX fuel shows a better pellet-
7 cladding mechanical interaction behavior due to the
8 higher creep rate of the MOX pellets. Addressing
9 mainly France, it shows the MOX is not limiting with
10 respect to plant maneuverability.
11 Next slide, please. This slide shows the
12 fuel rod growth is prediction against the measurement
13 of the UO_2, again the MOX fuel and the gadolinium
14 fuel. The MOX fuel is in blue in this representation.
15 So there is no bias due to the MOX presence in the
16 fuel rods.
17 DR. KRESS: Is the gadolinium mixed in
18 with the UO_2 --
19 MR. BLANPAIN: The gadolinium -- but we
20 don't use gadolinium fuel with MOX fuel.
21 CHAIRMAN POWERS: I notice on your slide
22 that you distinguish UO_2 with what is called ZY4,
23 which I'll guess is Zircaloy 4 cladding, and UO_2 with
24 M5 cladding. But you only have MOX with Zircaloy 4.
25 MR. BLANPAIN: Here in this slide, we only

1 have MOX with Zircaloy 4, yes. But we have MOX with
2 M5 cladding, but not including the very recent data.
3 CHAIRMAN POWERS: Now what I was curious
4 about is at the beginning of your presentation you
5 listed some 2400 fuel assemblies -- 1300 fuel
6 assemblies. I wonder, could you give me an estimate
7 -- I don't need a particularly accurate number -- what
8 fraction of those had M5 cladding and what -- Well,
9 that's the only number I need, is what fraction had M5
10 cladding.
11 MR. BLANPAIN: Yes.
12 CHAIRMAN POWERS: Just a rough estimate.
13 MR. BLANPAIN: Today, usually in France we
14 are using Zircaloy 4 cladding for our MOX assemblies.
15 We have some M5 fuel rods with MOX for experimental
16 purposes in France, but today the MOX product
17 delivered by Framatome France in Germany is M5. The
18 reference is M5.
19 So we have four reloads of MOX with M5 in
20 Bergdorf and in four reactors today in Germany.
21 MR. NESBIT: I think that would maybe be
22 tens of assemblies probably. It is relatively recent,
23 if I'm not mistaken, after the transition to M5. So
24 we are not talking, I don't think, about hundreds and
25 hundreds of M5.

1 MR. MEYER: At Cadarache they have
2 fabricated approximately 50,000 M5 fuel rods. Those
3 are for the German market.
4 MR. BLANPAIN: To answer your question,
5 it's the next one. You can see better about the clad
6 outer surface corrosion. That is also the calculation
7 against the measurement, and here the measurements all
8 came from the reactor at Finisberg in Germany.
9 That graph is a result of a measurement of
10 the rod of two assemblies, one three-cycle and another
11 four-cycle MOX assembly, and compared to the L5
12 database.
13 In blue we have the M5 database. In the
14 red points are the UO_2-M5 database on the KKP2
15 reactor, and the yellow points as well as the green
16 ones are MOX rods compared to the world database
17 showing that there is no MOX effect on cladding
18 corrosion. It is a measurement of 100 percent of the
19 rods in one assembly. Next.
20 That graph represents the pellets' density
21 evolution with burnup. So it is a measurement of the
22 pellets after irradiation, and it is also for the
23 comparison of MOX fuel to UO_2 fuel. You can see
24 there, there is no difference. The tendency is the
25 same, because the surface -- is only due to the

1 generation of fission products, and it is normally the
2 same for UO_2 and MOX fuel. Next, please.
3 Here we have the fission gas release
4 database. That is a database obtained from the
5 examination of rods irradiated in EDF reactors. So we
6 have here the UO_2 data in blue compared to the -- the
7 MOX data in blue compared to the UO_2 data in red.
8 You can see quite an increase of fission
9 gas release for the MOX. That corresponds to the end
10 of the cert cycle, and it is not -- The ranking is not
11 a certainty on the measurement, but is due to the
12 different heat rate experienced by the different rods
13 during the - mainly the -- of the irradiation cycle.
14 So the fission gas release is a function of the
15 temperature, and then to the -- experienced by the
16 fuel.
17 If you notice also that there is no burnup
18 enhancement due to the burnup when we see the blue
19 points at 50 and then a 60 -- because there is
20 normally a power decrease after the second -- cycle.
21 The next one.
22 This slide, higher fission gas release
23 sampled in MOX fuel. It explains we have neutronic
24 properties of the MOX, leading to higher linear heat
25 rates at medium and high burnup, but it is mainly in

1 the -- in EDF reactors, and also different pellet
2 radial power density distribution, leading to
3 different temperature, at higher temperature for the
4 MOX fuel at high burnup.
5 The physical properties: As I said
6 before, is due to the slightly lower thermal
7 conductivity of the MOX, leading to higher fuel
8 temperature. But it could be also due to the oxide
9 microstructure, to the presence of the plutonium rich
10 particles due to the MIMAS process can change the
11 mechanism of fission gas release due to the very high
12 local burnup and leading to the formation of dense
13 pore populations. But we think it is a very small
14 effect, and there is no -- As I said at the beginning
15 of the presentation, the contribution of the last
16 plutonium rich particles is quite small.
17 What is important to note is that the
18 Halden temperature threshold for fission gas release
19 is the same as for UO_2 fuel. That has been measured
20 several time sin the Halden reactor.
21 The next one, please. Here we have a
22 radial cut of a high burnup MOX pellet, showing that
23 there is no difference compared to the radial cut of
24 a UO_2 fuel. It is showing the same cracking pattern.
25 CHAIRMAN POWERS: This hits to a point

1 that Dr. Lyman raised, a question that he raised in
2 his presentation. I think it is fair to characterize
3 it as a question.
4 Was there any inherent difference in the
5 fragmentation of this MOX fuel relative to what we
6 have experienced in uranium dioxide fuel a we go up to
7 these burnups? I'll have to admit, had you not told
8 me this was MOX fuel, I probably would not have known
9 otherwise. I mean, it looks like pretty much the same
10 kind of fraction pattern that I am used to, but that
11 is not a statistical -- It's not a statistical set.
12 Do you have statistical data that suggests
13 that this is about the same or is just a qualitative
14 sentiment here?
15 MR. BLANPAIN: No. That is the cracking
16 pattern of the fuel after normal operation as compared
17 to UO_2 is the same. After the -- incident, UO_2 and
18 MOX fuel is roughly the same also. But with --
19 roughly the same. But what -- Some differences were
20 -- People have published that the MOX behaved
21 differently during the AI situation, after the --
22 test. But what we have seen is not a difference in
23 fracture of the MOX compared to UO_2.
24 If we can see the next figure, please.
25 That is the evolution of the plutonium rich particles

1 during irradiation. That is the period after three
2 irradiation cycles.
3 The plutonium rich particles -- The
4 evolution is like high burnup structure or the ring
5 structure with the formation of small bubbles and then
6 coalescing throughout the pellet center line due to
7 the high temperature.
8 Okay. But after the Cabri tests, we have
9 seen that, like for UO_2 fuel, we have the equation of
10 the grains, the equation of the UO_2 grains, but what
11 we have seen also -- and that is the plutonium rich
12 particles remained intact after the Cabri test.
13 So today the explanation is not
14 definitive, because we haven't seen the grain
15 equation, but around the UO_2 -- the UO_2 grains, and
16 not around the plutonium rich particles. Okay, next
17 one.
18 Now I conclude with the short and medium
19 term development. For economical reasons, MOX fuel
20 has to perform as efficiently as UO_2 fuel with regard
21 to the burnup and operational flexibility.
22 The burnup equivalence to uranium fuel
23 assemblies has been demonstrated in Germany,
24 Switzerland and Belgium. The discharge burnup is
25 around 50 in those countries.

1 In France, that parity between UO_2 and MOX
2 fuel is not rich today, but will be completed next
3 year. The licensing process is almost completed for
4 the 20 MOX licensed power plants, and that parity will
5 be to discharge rod burnup of 60, as for UO_2 fuel.
6 That parity must be established on a
7 medium or long term basis, of course. So we are to
8 work and to demonstrate that the MOX product can
9 follow the UO_2. Next slide.
10 Now to conclude: Extensive poolside and
11 hot cell examinations have demonstrated the excellent
12 behavior of the MOX fuel up to assembly burnup to
13 around 60. The performance of the current MOX is
14 equivalent to that of UO_2 in terms of discharge burnup
15 without any penalty on core operating conditions and
16 fuel reliability.
17 Now ongoing development are still
18 underway, and to demonstrate equivalence of UO_2 and
19 MOX fuel up to very high burnups. By that I mean that
20 we are working on UO_2 for a very, very high burnup.
21 For example, UO_2 -- to develop the UO_2 fuel with the
22 chromium fuel with large range to go to very high
23 burnup to increase the efficient retention.
24 We are working also on the MOX product in
25 the same way, to increase the range. Thank you for

1 your attention.

2 CHAIRMAN POWERS: Thank you for a most

3 informative presentation. Do members have any

4 questions they wish to pose to the speaker?

5 DR. BONACA: The MOX experience, the

6 European MOX, which has a different kind of isotopic

7 content of plutonium as well as different content of

8 UO_2. Are you going to say about the effect of those

9 differences on this experience or is somebody going to

10 address that today?

11 MR. NESBIT: Let me take a short first.

12 First of all, the issue that you bring up is addressed

13 at substantial length in our application, in the

14 topical report, and in some other materials which we

15 have provided the NRC.

16 We didn't make that a point of emphasis

17 today, because it is not one of those issues that is

18 really highlighted in the current contentions that are

19 before the licensing board. But let me make a couple

20 of statements about that.

21 Fundamentally, the major impact of the

22 isotopic differences is to lower the required

23 plutonium concentration in the fuel pellet, and what

24 that means is that the MOX we use is generally closer

25 to LEU than the MOX that is used in the European

1 experience.

2 The isotopic differences are addressed

3 specifically in the nuclear design topical report and

4 in the nuclear analyses by modeling the specific

5 isotopics that are in play there.

6 Also one other thing. It is the same

7 uranium we are using for our MOX.

8 CHAIRMAN POWERS: I thought their uranium

9 drank more red wine.

10 MR. NESBIT: It may.

11 DR. BONACA: I simply -- Regarding some of

12 the exhibits that we were shown, it would have been --

13 For example, there is an exhibit 24, fission gas

14 release of BWR MOX. It would be interesting to have

15 a comment that says, as to applicability to the

16 specifics that we are going to insert in the U.S.,

17 this is the expected -- I mean, I realize that you

18 have some information, but this is information that I

19 hadn't seen before.

20 MR. BLANPAIN: Of course, it is difficult

21 to do within half an hour.

22 DR. BONACA: I understand.

23 MR. BLANPAIN: And about the plutonium

24 content, of course, we have in our database fuel rods

25 with two percent of plutonium content up to 10

1 percent. From the EDF reactors it is from 2 at the
2 low plutonium content in the assembly at the beginning
3 to 7 today. It is higher content in our assemblies in
4 France. But we have data from higher plutonium
5 content from analytical experience from Halden or the
6 BR3 in Belgium or from Germany.
7 If we -- Between the 2 and 3 and 7-8
8 percent, there is no effect of plutonium content on
9 the BWR, but of course, there is no effect of the --
10 for us, the thermal mechanical point of view, there is
11 no effect of the isotopic composition on the thermal
12 mechanical behavior, because if you have a best
13 isotopic composition, that means few fission content.
14 You have to increase the total plutonium
15 content, and that is what we are doing today, because
16 for the MOX parity project, for example, the highest
17 plutonium content in the fuel rods will be around 10,
18 due to the evolution of the isotopic composition of
19 the reactor grade fuel. But the weapon grade fuel
20 will be enveloped by the experience, because the
21 average plutonium content will be 4.
22 DR. BONACA: I guess my questions are more
23 directed at a full -- whatever a full load with MOX
24 fuel will be rather than just the LTAs. The reason is
25 that you presented to us some limits that are used in

1 Europe to the amount of MOX fuel that you can insert
2 in a core, and they seem to be related to fission
3 product releases or whatever. That is what you
4 mentioned something there.
5 Now, you know, the plutonium composition,
6 particularly the abundancy of 239, may cause some
7 differences in this fission gas release in PWRs. In
8 the long run, I am interested in knowing how that
9 plays out in the amount of MOX fuel from weapon grade
10 that you would be inserting in the U.S. reactors.
11 Maybe that is not pertinent to the LTA presentation,
12 but that is why I was interested in those figures.
13 MR. NESBIT: It might also be a little
14 premature. Until we actually perform the safety
15 analyses for batch implementation, which are ongoing
16 at this time, and do the related analyses, we can't
17 come back and say there is a hard and fast limit.
18 Based on everything we have seen right
19 now, the 40 percent goal for batch implementation is
20 achievable, but we haven't completed the case at this
21 point.
22 DR. BONACA: That was the reason I was
23 leaving those questions. Okay.
24 CHAIRMAN POWERS: Let me follow up that
25 question. When you go to the weapons grade plutonium

1 feed into the material, will you get the same
2 distribution between particulate and matrix plutonium?
3 MR. BLANPAIN: So okay. In Europe
4 Framatome is using primary blend. The plutonium
5 content in the primary blend is around 30 percent. So
6 it is for evident economical reasons and also the
7 plant is designed for that.
8 As you know, we are using three different
9 plutonium content for one assembly, and we dilute
10 differently that primary blend to the secondary to
11 redefine the plutonium content. Okay?
12 So the overall experience we get from
13 those MOX fuels is a MOX fuel with 30 percent of
14 plutonium in the primary blend with a fission
15 density. It is a well known fission density, because
16 it is the same -- different kind of fuel.
17 So the reason why we go to the different
18 isotopic composition of the weapon grade fuel, we
19 decided to reduce the plutonium content in the primary
20 blend so to get the same fission density that we have
21 in our ARPM fuel.
22 CHAIRMAN POWERS: So your primary blend
23 will run more like 20 percent?
24 MR. BLANPAIN: Yes.
25 CHAIRMAN POWERS: And now when you come to

1 the final fabricated material, you will blend up with
2 a higher fraction of matrix plutonium or the same
3 fraction?
4 MR. MEYER: We expect it to be about 20
5 percent.
6 CHAIRMAN POWERS: But 20 percent -- What
7 we saw in the microstructural examination here is that
8 you have about 25 percent of your plutonium in
9 particulate, and the rest of it in matrix. I'm just
10 wondering if you are going to get the same split
11 there.
12 MR. NESBIT: I don't know the answer off
13 the top of my head.
14 CHAIRMAN POWERS: Any other questions?
15 Well, we very much enjoyed it. I can assure you, the
16 committee very much enjoyed your presentation. They
17 love to get into this.
18 I think we are now in a position to take
19 a well earned break, and so I will recess us until --
20 what is that, 11:35? 11:40. Ralph is being generous
21 today. We will recess until 11:40.
22 (Whereupon, the foregoing matter went off
23 the record at 11:23 a.m. and went back on the record
24 at 11:42 a.m.)
25 CHAIRMAN POWERS: Let me apologize for Mr.

1 Blanpain. I did not do my job of summarizing his
2 essential points, which I took it to be that under
3 normal operations, MOX and your AM dioxide fuels are
4 about -- are essentially the same. There might be
5 some differences for a reactivity initiated event,
6 perhaps because there is an earlier onset to the
7 equivalent of what we could call the rem effect.
8 He also made a point that the pellet clad
9 mechanical interactions might be somewhat reduced
10 because of a higher creep rate for the fuel. There
11 might be other ramifications of a higher creep rate.
12 A quick and dirty summary of a very nice
13 presentation. If you have no objections, then we will
14 proceed on to discussing the fuel assembly design with
15 George Meyer.
16 MR. MEYER: We expect My name is George
17 Meyer. I'm the MOX Fuel Qualification Manager. I
18 work for Framatome ANP in the U.S.
19 CHAIRMAN POWERS: You got to speak right
20 into that thing and put your nose right up to it.
21 MR. MEYER: I've got three topics, and
22 I'll try to keep it brief. I will tell you about the
23 lead assembly design, a little bit about the design
24 evaluation, and I will talk about the quality
25 assurance programs that we have in place for the lead

1 assembly fabrication.

2 CHAIRMAN POWERS: Let me just interject,

3 George, that I did become confused over the exact

4 design between the SER and the recent letter. It left

5 me somewhat exactly what these rods will look like.

6 MR. MEYER: Recent letter?

7 CHAIRMAN POWERS: The April 16th letter,

8 I think, last Friday. I'll have to look to see what

9 the date is.

10 MR. NESBIT: That letter would not have

11 impacted the design of the MOX fuel assembly itself.

12 That letter, I think, if it is the same one, addressed

13 the issue of the other Westinghouse lead test

14 assemblies.

15 CHAIRMAN POWERS: I believe it contained

16 a listing of what the various geometries of the rods

17 are.

18 MR. NESBIT: Right.

19 CHAIRMAN POWERS: And that did not seem to

20 square with the description I had in the SER. That

21 may have been my poor reading.

22 MR. NESBIT: It came from -- The Framatome

23 assembly information came from the MOX fuel design

24 report.

25 MR. MEYER: Okay, next slide.

1 The MOX lead assembly is a U.S. fuel
2 assembly design that integrates MOX pellets into the
3 fuel rods. The assembly design is the same design as
4 the advanced Mark-BW fuel assembly.
5 This design is presented in two topical
6 reports, the first being one that presents the fuel
7 assembly itself, the Advanced Mark-BW, and the second
8 is the MOX fuel design report.
9 Can you hear all right? Good.
10 This design is an evolution of the Mark-
11 BW. It is a 17 x 17 PWR fuel assembly which has
12 operated successfully at McGuire, Catawba, Trojan and
13 Sequoia, and as of March 2004 over 2800 Mark-BW fuel
14 assemblies have been supplied.
15 The Advanced Mark-BW is the terminology
16 for the latest evolution of that design, incorporating
17 updates that have been made over the years since the
18 first lead assemblies of this design were introduced
19 in 1987.
20 The Advanced Mark-BW is also represented
21 by four lead test assemblies which operated at North
22 Anna Unit 1 for three cycles, completing radiation in
23 2002 with a fuel assembly burnup of about 52 gigawatt
24 days per ton uranium, and one of those lead assemblies
25 then was reinserted for a fourth burn, and it is

1 completed its irradiation at North Anna Unit 2 now.
2 It is completing its irradiation this month with a
3 lead fuel rod burnup of 71.7 gigawatt days per ton
4 peak rod. Next slide.
5 The fuel assembly design -- This is a
6 picture of the -- or a schematic picture of the lead
7 assembly design, and it is, as the note says,
8 identical to the Advanced Mark-BW.
9 Design features listed: M5 structural
10 tubing; M5 mixing grids; M5 fuel rod cladding; TRAPPER
11 bottom nozzle. As I mentioned earlier, all of these
12 features have been integrated into the design over the
13 last several years.
14 The things that constitute the Advanced BW
15 and are used in the MOX lead assemblies include M5
16 mixed-van mixing grids and the TRAPPER debris filter
17 bottom nozzle.
18 The only MOX-specific features are, in
19 fact, the fuel pellets, with a minor change to the
20 fuel rods. One point that I want to make here is that
21 the design, as I said earlier, is an integration of
22 existing technologies and, therefore, the lead
23 assemblies represent a demonstration of that
24 integration rather than a test of a new design. Next
25 slide.

1 DR. KRESS: Before you leave, a couple of
2 questions. Has the Advanced Mark-BW -- Is that
3 getting a separate approval from NRC or is it part of
4 the MOX fuel?
5 MR. MEYER: It has a separate approval.
6 DR. KRESS: It already has?
7 MR. MEYER: Well, it was in parallel with
8 the -- It has a draft SER, as does the MOX fuel design
9 report, but it is addressed in a separate report, both
10 reviewed at the same time.
11 DR. KRESS: Do the mixing vanes and the
12 mixing grids have a significant effect on the LOCA
13 analyses?
14 MR. MEYER: They are considered as a part
15 of the LOCA analyses.
16 DR. KRESS: They are considered in there?
17 And you have a database to back that up, or what its
18 effect is?
19 MR. MEYER: The mixing grids are the same
20 mixing grids that have been used in the Mark-BW fuel
21 assembly design since 1987.
22 DR. KRESS: Oh, they are the same?
23 MR. MEYER: Yes.
24 DR. KRESS: Somehow I thought the --
25 MR. MEYER: What is added in the new

generation is the mix-van mixer, and that has the same vanes, and it is included and addressed in the LOCA analysis.

DR. TRIAFOROS: Excuse me. You wouldn't be discussing new generation here, is the Advanced design, and it is the Mark design? Right?

MR. MEYER: Wrong terminology.

DR. TRIAFOROS: Excuse me. Yes.

MR. MEYER: This is the Advanced Mark-BW. Yes.

DR. LEITCH: I am a little confused about the length of the fuel rods. The fuel rods are slightly longer in this design, but are the overall dimensions of the fuel assembly the same -- the overall dimensions?

MR. MEYER: Dimensions of the fuel assembly are the same. The next slide shows the fuel rod dimensions.

This slide shows some of the key design parameters for the fuel rod, and it compares the MOX lead assembly fuel rod to the Advanced Mark-BW fuel rod. In fact, that rod on the right is the same design that was used in the North Anna lead assemblies. So they are both M5 alloy. It is a .25 inch difference in overall rod length.

1 They have the same cladding diameter and
2 thickness, the same pellet diameter, the same gap
3 size.
4 DR. LEITCH: The actual fuel is the same?
5 This .25 inches is just to give you more gap at the
6 top?
7 MR. MEYER: .25 is to give you more
8 quantum volume to accommodate the higher fission gas
9 release.
10 MR. NESBIT: It is the same fuel stack
11 height as the resident LEU fuel.
12 MR. MEYER: Stack height is not shown, but
13 it is the same for the UO_2 and the MOX fuel and for
14 the co-resident fuel in the Catawba core. It is 144
15 inches.
16 Okay. The design burnup is slightly
17 different, and for the lead assemblies we are
18 intending to take them to slightly under 60,000 peak
19 rod burnup in three cycles. That is intended to
20 support future batch operations to a burnup limit of
21 about 50,000 megawatt days per ton.
22 CHAIRMAN POWERS: Here is where it is
23 unknown, fuel rod length, why I got a little bit
24 confused here; because in this April 16th letter we
25 have fuel rod lengths for the RFA and the NGF listed

1 at 152.8, whereas the Mark-BW/MOX1 is 152.4.

2 Yet the SER says that the MOX is longer.

3 MR. MEYER: That is compared to the Mark-

4 BW and not to the RFA -- Advanced.

5 CHAIRMAN POWERS: Well, all this leads to

6 confusion on exactly what is in this core.

7 MR. MEYER: Well, the comparisons made in

8 the fuel design report are made to the Advanced Mark-

9 BW, because that is the base design, the base

10 Framatome fuel design for the MOX lead assemblies.

11 CHAIRMAN POWERS: I see.

12 MR. NESBIT: The Westinghouse RFA fuel is

13 described in some Duke submittals and also in the

14 safety analysis report.

15 MR. MEYER: I mentioned that the fuel rods

16 shown on the righthand column are the same rods, same

17 rod design as in the North Anna lead assemblies, which

18 is being taken out to a burnup of approximately 71.7

19 gigawatt days per ton rod burnup in an ongoing

20 irradiation. Next slide.

21 I don't plan to go into the details of the

22 design evaluation unless you have questions about it.

23 What I want to say is that the design evaluation is

24 presented in the MOX fuel design report. It addresses

25 the requirements of Standard Review Plan 4.2.

1 For the fuel rod, which is different than
2 UO_2 in the sense that it uses MOX pellets, all of the
3 evaluations use models that have been adjusted as
4 necessary for MOX. It uses the COPERNIC fuel
5 performance code which has benchmarked to the MOX
6 data, and in particular the data that Mr. Blanpain
7 showed you, and it uses models that have been shown to
8 be appropriate for MOX and addresses the criteria, the
9 same criteria that are addressed for UO_2 fuel.
10 Fuel assembly evaluations are, for the
11 most part, not affected by the use of MOX fuel. Where
12 they are affected -- for example, in evaluating the
13 fuel assembly lift and hold-down analyses where the
14 spring constants could be affected by the fluence --
15 that effect is incorporated into those analyses and
16 those evaluations.
17 Those design evaluations are presented in
18 the MOX fuel design report and, where appropriate,
19 reference back to the Advanced Mark-BW design topical
20 report. Next slide.
21 Framatome ANP is the fuel designer of the
22 MOX fuel assemblies. The lead assemblies will be
23 fabricated in Europe under the Framatome ANP quality
24 assurance program. That program meets the
25 requirements of 10 CFR 50, Appendix B.

1 It is a program that has been globally
2 implemented within Framatome ANP.
3 CHAIRMAN POWERS: Is this, in fact, an
4 ISO9000 --
5 MR. MEYER: It is, yes.
6 CHAIRMAN POWERS: There is enough
7 equivalence?
8 MR. MEYER: ISO9000, NQA1, KTA1401. It
9 addresses all of the requirements for the various
10 regulators and organizations.
11 The suppliers -- Each of the suppliers
12 that will be providing components for the lead
13 assemblies are or will be qualified by Framatome under
14 this QA program. That includes Los Alamos National
15 Laboratory for the supply of the plutonium oxide
16 powder. It includes COGEMA Cadarache facility for the
17 fabrication of the pellets and fuel rods. it includes
18 COGEMA MELOX facility for the fabrication of the lead
19 assemblies.
20 CHAIRMAN POWERS: Whenever one thinks
21 about plutonium dioxide derived from weapons
22 components, one immediately punks in, gee, what is the
23 gallium contamination of this. Contaminating
24 plutonium dioxide with gallium, of course, is a
25 difficult chore, since gallium is not favorably

1 disposed to stand the oxide very well. Can you tell
2 us what your spec is?
3 MR. MEYER: The spec is 300 ppb in the
4 plutonium oxide powder, and that is achieved by
5 polishing the powder by removing the contaminants, and
6 that is done at Los Alamos.
7 The 300 ppb in the powder produces a
8 component or an effect of about 15 ppb in the
9 resulting pellets. That is consistent with what has
10 been observed in irradiated UO_2 fuel pellets.
11 CHAIRMAN POWERS: Just because of the
12 yield of gallium in the spectrum, in the fission
13 spectrum?
14 MR. MEYER: No, because we have reduced
15 the gallium to the 300 ppb level. The incoming feed
16 materials have gallium on the order of one percent.
17 CHAIRMAN POWERS: Yes.
18 MR. MEYER: So we are reducing that by
19 polishing -- by putting it through an ion extraction
20 chamber, and to remove the contaminants and the
21 resulting powder, the plutonium oxide powder, meets a
22 spec which has a maximum gallium limit of 300 ppb.
23 MR. NESBIT: Dr. Powers, was your question
24 about the gallium in uranium oxide fuel or MOX?
25 MR. MEYER: Oh, I'm sorry.

1 CHAIRMAN POWERS: Well, he said this is
2 similar to what you get in the uranium dioxide fuel,
3 and I asked if just because of the gallium yield --
4 MR. MEYER: Oh, no, no. This is un-
5 irradiated uranium fuel.
6 CHAIRMAN POWERS: Just a normal feed.
7 MR. MEYER: I misunderstood the question.
8 CHAIRMAN POWERS: And do you -- This is a
9 question on which an "I don't know" answer would not
10 be surprising. Do you have any evidence of the
11 gallium attempting to segregate itself out as a
12 distinct phase?
13 MR. MEYER: In the pellets?
14 CHAIRMAN POWERS: In the pellets, yes.
15 MR. MEYER: There is no evidence. There
16 is an experiment managed by Oak Ridge, an irradiation
17 at the advanced test reactor that has irradiated MOX
18 pellets that were fabricated at Los Alamos. I don't
19 know if you are familiar with that experiment, the
20 average power test.
21 Those pellets had gallium levels on the
22 order of 1 to 3 ppm. That experiment just concluded
23 the irradiation phase, 50,000 megawatt days per ton
24 burnup. The PIE data is available for 20, 30 and 40
25 gigawatt days per ton irradiations. It shows no

1 evidence of separation, shows no evidence of any
2 detrimental effects from the gallium.
3 CHAIRMAN POWERS: Thank you.
4 MR. MEYER: Another comment on the quality
5 assurance: All of the non-fuel components, the fuel
6 assembly components, the cladding, the grids,
7 etcetera, are supplied by Framatome ANP, and those are
8 the same components that are supplied routinely for
9 the Advanced Mark-BW fuel assembly design.
10 So to summarize, the lead assembly is an
11 integration of European MOX technology into the U.S.
12 fuel assembly design. It is not a new design. It is
13 an existing design with different pellets.
14 The design evaluation uses approved
15 methods that have been shown to apply to MOX, that
16 have been submitted to the staff for evaluation, and
17 approved.
18 The lead assembly activities, including
19 fabrication, are performed in accordance with the
20 Framatome ANP quality management system.
21 We consider the lead assemblies are a
22 demonstration rather than a test, since they represent
23 the integration of existing technologies.
24 Thank you. That's all I have.
25 CHAIRMAN POWERS: Any questions of the

1 speaker?

2 DR. RANSOM: Just a clarification on the

3 notation. You refer to RFA, NGF and then now this

4 Mark-BW MOX-1. In your presentation you've got the

5 MOX lead assembly and the Advanced Mark-BW. What is

6 this Advanced Mark-BW?

7 MR. MEYER: The Advanced Mark-BW is the

8 latest evolution of the Mark BW, and physically it is

9 -- External to the fuel rod, it is identical to the

10 Mark-BW MOX-1 assembly.

11 The designation of Mark-BW/MOX-1 is the

12 designation chosen for the MOX fuel design. The

13 Advanced Mark-BW designation is the equivalent UO_2

14 fuel assembly design.

15 DR. RANSOM: And they are both slightly

16 different than the NGF?

17 MR. MEYER: The NGF is a Westinghouse fuel

18 design, as is the RFA. What I am speaking to here are

19 the Framatome fuel designs.

20 MR. NESBIT: If I can maybe respond as

21 well and answer in a slightly different way that might

22 help clarify this.

23 The Framatome product, the Advanced Mark-

24 BW, is their product that they market to customers

25 such as North Anna. The Advanced Mark-BW MOX-1 is the

1 modification of that product for our program, and that
2 modification consists of lengthening the fuel rod and
3 putting MOX pellets in instead of uranium oxide
4 pellets.
5 The Westinghouse assemblies are,
6 obviously, a very different design. Well, they are
7 similar in that they are 17 x 17 fuel, and they have
8 similar pressure drops and things like that, but they
9 are Westinghouse components and grids.
10 DR. RANSOM: Well, have these Advanced
11 Mark-BW UO_2 assemblies been used in U.S. reactors?
12 MR. MEYER: Yes. The Advanced Mark-BW, as
13 shown there, has been used as an LTA. The Mark-BW
14 with some of the features that we call -- that
15 constitute the Advanced Mark-BW has operated in
16 various reactors.
17 As I said earlier, we have delivered over
18 2800 Mark-BW fuel assemblies, and those have operated
19 successfully. The features that constitute the
20 Advanced Mark-BW have been integrated over the years.
21 So the design has evolved, and what we did in the
22 topical report for the Advanced Mark-BW was to put all
23 of the features that had evolved over the years into
24 one place for one licensing submittal that provides a
25 description of that final -- called the final product,

1 the Advanced Mark-BW.

2 Then that final product with all of those

3 features together has operated as an LTA at North

4 Anna, and the first complete batch of the product that

5 has all of the features described as Advanced Mark-BW

6 will be loaded into North Anna in the coming months.

7 DR. RANSOM: Are these Advanced Mark-BW

8 assemblies made in like Richland, Framatome?

9 MR. MEYER: They are made at Framatome

10 Lynchburg.

11 DR. RANSOM: And Richland also?

12 MR. MEYER: The pellets are made at

13 Richland, but the fuel assemblies are made at

14 Lynchburg. Framatome in the U.S. is making all of its

15 PWR fuel in Lynchburg in the future and its BWR fuel

16 in Richland.

17 DR. RANSOM: Thank you.

18 DR. LEITCH: Is it premature to talk about

19 the post-irradiation test program? At 60,000 or so

20 megawatt days per ton, I guess we are talking three

21 cycles or so before we are to that point.

22 MR. MEYER: I can talk to that. We plan,

23 first of all, a poolside PIE, another stroke of PIE

24 after each cycle of operation. That would include the

25 typical nondestructive evaluations. It would include

1 visuals for overall appearance to assess the need for
2 additional work, visuals of both fuel rod and fuel
3 assembly.
4 It would include measurements on fuel
5 assembly growth and fuel rod growth and the gap
6 closure, and it would include evaluations of bow and
7 distortion.
8 After the completion of the second cycle
9 of irradiation, we expect to hold out two or three
10 assemblies to reinsert one or two for the third burn.
11 The assemblies that are held out, then we will do what
12 we call an extended PIE, and the scope of that depends
13 to some extent on what has been learned from the
14 visuals and the other work. But we would expect to do
15 measurements such as grid width and fuel rod oxide
16 thicknesses and R-68 drag testing and rod to rod
17 spacing, ITML profile.
18 We would also then at the end of the
19 second cycle of irradiation where we will have
20 achieved the burnup approaching 50,000 megawatt days
21 per ton rod peak burnup -- we expect to take rods out
22 to a hot cell for hot cell examinations. those
23 examinations would include puncture, rod pressure,
24 fission gas release, cladding metallography, cladding
25 ductility, fuel pellet analyses, and fuel pellet

1 ceramography as well as burnup analyses.

2 DR. LEITCH: While you are doing this

3 then, if I recall you correctly, then a couple of LTAs

4 will still be in the core?

5 MR. MEYER: Yes, for their third burn.

6 DR. LEITCH: When those come out, you will

7 do similar tests?

8 MR. MEYER: When those come out, we have

9 -- At this point we are considering it to be an option

10 for additional hot cell work, and the decision to do

11 that would be dependent on how the program is

12 proceeding and what the experience is.

13 DR. LEITCH: Thanks.

14 MR. MEYER: You're welcome.

15 CHAIRMAN POWERS: Thank you very much. We

16 will move on to Mr. Eller.

17 MR. ELLER: My name is Jim Eller. I work

18 for Duke Power Company. Our role in the MOX fuel

19 project is to provide irradiation services. Because

20 Duke has been licensed to do their own reload design

21 for many years, irradiation services means more than

22 just putting fuel assembly in the core and irradiating

23 it.

24 Some of the other services that are

25 provided are the standard kinds of analytical services

1 that we perform to support LEU cores. One area of
2 those services is nuclear analysis, and that is the
3 subject of my presentation.
4 The first slide is a general overview of
5 the presentation. I have a couple of slides that
6 describe the analytical models that we use in nuclear
7 analysis. I have several slides that describe the
8 benchmarking process that is used to define the
9 fidelity of the codes, to show their ability to
10 predict the physical world.
11 Then at the end of the presentation I have
12 a couple of slides that give information about the
13 core design that we have just completed that would
14 include the four MOX LTA.
15 Duke Power uses computer models that come
16 to us from Studsvik Scandpower Corporation. The name
17 of their package of codes is called Core Management
18 System or the CMS package. Studsvik Scandpower --
19 these codes are used by various organizations in
20 Europe, North America and Asia, and we have been using
21 them at Duke Power since the mid-1980s in one form or
22 the other. Of course, the codes have evolved over the
23 years.
24 They are currently used by about 55
25 organizations in 11 countries to support reactor core

1 design and operation of many BWRs and many PWRs in, as
2 I said, Europe and Asia and North America.
3 Those core designs perhaps number to as
4 many as 2000 fuel cycles since the 1980s, and some of
5 those fuel cycles have been fuel cycles in Europe that
6 included MOX and LEU fuel. Next slide.
7 I have just a brief bit of information
8 about each one of the major programs. The first is
9 CASMO-4. It is a two-dimensional, multi-group
10 transport theory model. We use it to analyze the
11 detailed behavior of each unique fuel lattice in the
12 core, and fuel lattice does not mean fuel assembly.
13 A single fuel assembly may have two or three or four
14 unique lattices along its axial high.
15 If you have a fuel assembly that has a
16 blanket and a BP, there may be regions where the BP is
17 present and regions where there's central enrichment
18 and no BP. So there are more than one lattice in each
19 assembly, and each one of those unique situations is
20 modeled in two dimensions with CASMO-4.
21 CASMO-4 is executed for the range of
22 temperatures and lattice configurations that would
23 exist in the reactor or in the lattice itself, and the
24 combination of all that, as you can imagine, produces
25 a lot of information from CASMO, cross-sections and

1 discontinuity factors that are used in the core model.
2 CMS-LINK gathers all that information
3 together and tabulates it in a fashion that the core
4 model can use, and it is in a single file now that the
5 core model reads.
6 The core model is SIMULATE-3 MOX. It is
7 a three-dimensional, two-energy group diffusion theory
8 model. It includes enhancements to model cores
9 containing LEU and MOX fuels. We generally run this
10 model -- We can run this model in either full or
11 partial core geometries, depending on what the
12 symmetry of the analysis requires.
13 We usually run the model with four radial
14 nodes per assembly and 24 axial nodes in the active
15 fuel column. So the nodalization of the model would
16 be -- The x-y would be half of an assembly pitch, and
17 the z would be six inches. That is the normal
18 nodalization of the model. We use the same
19 nodalization, regardless of MOX or LEU in the core.
20 SIMULATE-3K MOX is an extension of the
21 SIMULATE code that is used to model fast reactor
22 transients, and in the work that we have done so far
23 to support the licensing process and the benchmarking
24 process, it was used to interpret the signals that we
25 get when we do dynamic rod worth measurements at the

1 beginning of each cycle. Next slide.

2 I am now moving on into the subject of

3 benchmarking a little bit. Benchmarking is simply a

4 comparison of the predictions that come from the

5 models to measurements that we get when we operate the

6 reactor or measurements that are made in laboratory

7 experiments.

8 The type of measurements that are made

9 during the operation of the reactor: Some of them are

10 made at the beginning of the cycle during what we call

11 zero power physics testing where we measure control

12 rod worth, temperature coefficients, and we also take

13 some careful boron concentration samples -- excess

14 reactivity.

15 DR. BONACA: I had a question. You said

16 that SIMULATE, you have four regular nodes per

17 assembly. How do you get your pin to average peaks

18 per assembly?

19 MR. ELLER: Say that again, please.

20 DR. BONACA: You said that the SIMULATE

21 simulates four regular nodes per assembly.

22 MR. ELLER: Right.

23 DR. BONACA: And the question I had is how

24 do you derive your pin to average for the assembly?

25 MR. ELLER: We can request many edits from

1 the codes. When we requested an assembly that
2 requires an assembly average to be performed, that is
3 done internal to the code.
4 DR. BONACA: Okay.
5 MR. ELLER: So if we wanted hot pin to
6 assembly average, there is an edit for that, and the
7 averaging down to a full assembly and the
8 normalization that is required for all that is taken
9 care of internal to the code.
10 DR. BONACA: So you do have a fine mesh
11 capability?
12 MR. ELLER: Yes.
13 MR. NESBIT: Well, the SIMULATE performs
14 a 10-power reconstruction. It is kind of state of the
15 practice, I would say, in the industry now, in order
16 to get the detailed pin information out of a nodal
17 code such as SIMULATE.
18 MR. ELLER: The primary solution in
19 SIMULATE is a nodal solution, the fusion theory.
20 SIMULATE uses information that comes from CASMO about
21 the pin by pin power distribution and discontinuity
22 factors at the boundary of the nodes and reconstructs
23 the pin power distribution that would exist in the
24 core if it had performed a pin by pin analysis.
25 DR. BONACA: So you perform comparisons,

1 and you have topical reports. You submit all that?

2 MR. ELLER: Yes, sir. The model and that

3 function and capability has been used at Duke Power

4 for LEU cores for many years, and it is in various

5 topical reports, and we have repeated that work for

6 cores that contain MOX fuel. I'll speak to that a

7 little more as I go along.

8 DR. BONACA: Okay.

9 DR. RANSOM: With the nodalization you

10 talked about using for SIMULATE, then does it include

11 the entire core loading, assembly by assembly?

12 MR. ELLER: Yes, sir.

13 DR. RANSOM: So you have nodalized all

14 assemblies?

15 MR. ELLER: Yes, sir.

16 DR. RANSOM: What, to a quarter of the

17 core then at a time?

18 MR. ELLER: We can run it either way. For

19 analyses where the core has symmetry about the core to

20 core, we only model the core to core. But in an

21 analysis like a rod ejection or a dropped rod where

22 there is no symmetry in the core, we run the model in

23 the full core, and when we expand the model to full

24 core, the nodalization stays the same.

25 DR. RANSOM: What do you do for the

1 thermal hydraulics? Are you going to talk about that
2 later?
3 MR. ELLER: The code does thermal
4 hydraulics in a simplified fashion. Detailed channel
5 thermal hydraulics are performed by a separate set of
6 codes and a separate group of people, and the primary
7 code there is VIPER. I am not prepared to speak very
8 much about that today, but we have other people here
9 that can talk about the detailed thermal analysis, if
10 you have questions.
11 DR. RANSOM: Well, out of this
12 calculation, do you get the rod temperature,
13 especially if you have some a rod ejection or
14 analysis?
15 MR. ELLER: In the SIMULATE model itself,
16 we don't get rod temperature out of that model. The
17 code calculates the simple rod temperature so that we
18 can look up the appropriate cross-sections.
19 When we go to the SIMULATE-3K model, if we
20 were to use that code for rapid transients where fuel
21 temperature is very important, there is an explicit
22 pin conduction model in that code, and it provides
23 more detailed calculation of the pin fuel temperature.
24 MR. NESBIT: As a matter of clarification,
25 what Jim is talking about is primarily the steady

1 state core design calculations that are performed.
2 What you are asking about are the safety analysis type
3 applications, which are typically done using inputs
4 derived from the core calculations, but with other
5 codes.
6 DR. RANSOM: Okay.
7 MR. ELLER: Okay, back to the benchmarking
8 slide. Much of the information, as I was saying,
9 comes from measurements that are taken during power
10 reactor operation, and I listed those previously.
11 Obviously, we have a lot of historical
12 data from McGuire and Catawba, a lot of historical
13 measurements, and we use those and compare them to
14 predictions that come from these enhanced models. But
15 all of those cores contained only LEU fuel, and in
16 order to make a statement about the fidelity of the
17 models for cores containing a mixture of MOX and LEU
18 fuel, we obviously have to go somewhere else and find
19 measure data.
20 So we went to data from the French
21 reactor. St. Laurent has operated for many cycles
22 with MOX fuel. It is very similar to a three loop
23 Westinghouse plant like North Anna, for example, 17 x
24 17 fuel, etcetera.
25 They make the same types of physics

1 measurements at the beginning of cycle. They take the
2 same type of flux maps during the depletion of the
3 cycle. The in-core detectors are functionally very
4 similar.
5 So we get very equivalent types of
6 measurements from the St. Laurent reactor that we get
7 from our own reactors. The total body of data -- of
8 measurement data that we benchmark against there is
9 approximately six fuel cycles for each reactor,
10 McGuire, Catawba and St. Laurent, so a total of 18
11 fuel cycles, as I recall.
12 The data that comes from power reactor
13 operations, the measurements that come from power
14 reactor operations is not detailed enough for us to
15 verify the models to the extent that is required to
16 support reload design, and the specific example that
17 I am talking about is the flux mapping and the power
18 distributions that are measured during operations are
19 assembly by assembly power distributions.
20 When we do reload design, we have many
21 design criteria that are based on the fuel pin or on
22 the channel. So the power reactor data doesn't
23 provide enough information for us to characterize the
24 fidelity of the codes on a pin by pin basis, as we
25 have to.

1 In order to get at that fidelity inside
2 the fuel lattice on a pin by pin basis, and in order
3 to get at how well this pin power reconstruction
4 process works, we have always had to go to critical
5 experiments where the power distributions are measured
6 on a pin by pin basis.
7 The experiments that we have used several
8 times in the past are the B&W LEU experiments. They
9 contain critical arrays of fuel pins that were LEU
10 only, but there was some gadolinium in those. We
11 don't use any of the gadolinium pins, but these
12 experiments are used to qualify the performance of the
13 code for LEU fuel. We have repeated that work with
14 these codes.
15 Again because there is no MOX in those
16 experiments, we had to go somewhere else to get
17 additional data. So one place to go to is the SAXTON
18 experiments which are multi-region LEU/MOX experiments
19 performed in the Sixties and sponsored by
20 Westinghouse, I think.
21 These experiments, while they are very
22 old, they contained plutonium which had a Pu^{239} content
23 of 90 percent, which approaches what is labeled
24 weapons grade material.
25 We also got some additional measured data

1 from experiments that had been performed in France.
2 These EPICURE and ERASME experiments have the
3 advantage of having a geometry in the center of the
4 experiment that is geometrically similar to a 17 x 17
5 fuel assembly.
6 The EPICURE and ERASME experiments also
7 have poison pins in the arrays that are like the types
8 of poisons that we use in our PWRs, and this whole
9 body of experimental data allows us to do fairly
10 voluminous analysis of how well this pin power
11 reconstruction works inside the core simulator.
12 So if you look at the benchmark analysis
13 as a whole, we believe that it covers a wide range of
14 reactor materials and operating conditions like you
15 would find in the operation at McGuire and Catawba.
16 Any one piece of it may have some deficiencies, may
17 not be the perfect measurement to compare against, but
18 the package as a whole, we think, provides a very
19 robust analysis.
20 In general, the results from this
21 benchmarking work show no significant trends or
22 deficiencies related to MOX fuel. When you compare
23 the results from St. Laurent to the McGuire and
24 Catawba, you don't see any significant differences or
25 trends there. The same for the experiments, the

1 critical experiments that included MOX fuel or
2 included only LEU fuel.
3 DR. RANSOM: By deficiencies here, you
4 mean different designs. Is that right?
5 MR. ELLER: There are no biases that we
6 see related to MOX. The comparison is never perfect.
7 There are always differences between prediction and
8 measurement.
9 DR. RANSOM: Well, I'm interested in
10 whether there is any significant difference between
11 what you would predict for LEU fuel and the MOX fuel.
12 MR. ELLER: No. There are differences,
13 and I can't give the exact numbers in the meeting,
14 because the French are very protective of their data,
15 and we marked that proprietary in our topical report.
16 The topical report on all of this
17 benchmarking process and the statistical treatment of
18 the uncertainties and biases are provided in that
19 report. A summary of that topical report was also
20 presented and a paper at an ANS meeting last fall.
21 DR. RANSOM: You are referring to the Duke
22 Power Company report?
23 MR. ELLER: Yes, sir.
24 DR. RANSOM: PPC 105?
25 MR. ELLER: Yes, sir.

1 MR. NESBIT: I think maybe a pertinent
2 point that we can make in this meeting is that the
3 results of the -- relative to the MOX fuel and the LEU
4 fuel were so similar that we just ended up using the
5 LEU fuel uncertainties as our overall uncertainties.
6 DR. RANSOM: Is all that in your submittal
7 or the -- to the NRC?
8 MR. NESBIT: Our reference to the topical
9 report. It's in the topical report.
10 MR. ELLER: Other questions? Next slide.
11 Moving on the subject of the core design
12 that would contain the four MOX lead assemblies, we
13 have some additional design criteria that we have
14 placed on ourselves that are above and beyond the LEU
15 fuel. One of them is that no control rods will be
16 placed in the MOX fuel assembly in the first or second
17 cycle of irradiation.
18 That's pretty much a given in the first
19 cycle, because it is going to contain burnable poisons
20 like all the other feed fuel does.
21 A second design criteria that is specific
22 to MOX is that we made a commitment that at least two
23 of the MOX fuel assemblies will be placed in locations
24 that are instrumented. That is to say, locations that
25 an in-core detector will pass through when flux maps

1 are taken.

2 We have a strong preference to place all

3 four of the assemblies in instrumented locations.

4 Then as I will show in a minute, the current design

5 puts the assemblies in core locations C-08 and its

6 symmetrics which are fully instrumented around the

7 core.

8 The MOX fuel assembly power peaking must

9 not lead the core during nominal completion, and I

10 will show a table that shows these power levels in a

11 couple of slides.

12 The analysis -- The detailed analyses that

13 take places through the summer and into the fall this

14 year will check the power distributions, both for

15 nominal and off-nominal operations, that occur in the

16 MOX assembly, and verify that those power

17 distributions have acceptable margins through all the

18 MOX specific design limits that are generated by the

19 mechanical analyses and the thermal hydraulic

20 analyses.

21 The point being there is that, as the

22 design work proceeds, we are doing very specific

23 analysis for the MOX LTA core and the MOX fuel that is

24 in that core. There aren't any fudge factors being

25 applied for MOX.

1 In the next slide, which doesn't show up
2 very well, I have shown a picture of the bottom right
3 quadrant of the full core. Each cell represents an
4 assembly location. The cell in the top left of the
5 picture which is labeled H-8 would be the center
6 assembly in the physical core.
7 The cells which are highlighted in yellow
8 are assembly locations that are feed LEU feel, fresh
9 feed LEU fuel. The locations that are magenta or
10 darker shaded in core locations C-8 and H-13 are the
11 locations of the MOX fuel assemblies. Those are on
12 the major axis, and that represents a total of four
13 assemblies in the full core.
14 DR. LEITCH: Say that again, Jim. That is
15 what puzzled me. It looks like there's eight MOX
16 assemblies.
17 MR. ELLER: We knew that was going to
18 happen.
19 DR. LEITCH; But you are saying that this
20 is the major --
21 MR. ELLER: Yes, that is the major axis.
22 DR. LEITCH: So one of these is reflected
23 in the other quadrant?
24 MR. ELLER: Yes, sir. This picture shows
25 two major axes, and there are two other major axes in

1 the core. So there's two other assemblies that are
2 not represented in this picture. If I had shown the
3 full core, we would have not been able to see it
4 either.
5 DR. LEITCH: Okay, I understand.
6 MR. ELLER: The information in each cell
7 indicates the initial enrichment of the LEU fuel or
8 the initial total plutonium concentration in the MOX
9 fuel locations. The second number is an LBP
10 identifier that tells me how much burnable poison is
11 in the assembly. Obviously, the burnable poisons are
12 in the fresh fuel only.
13 Then there is a batch ID number, and the
14 last value in each cell is the hot pin average power
15 in each fuel assembly at 4 EFPD nominal conditions.
16 So you can look in this picture and see that the MOX
17 hot pin was 1.37 at this burnup, and the hot pin in
18 the core is over in location G-8, I think, which is
19 1.434. So that is an indication of how far behind the
20 lead in the core the MOX fuel is running.
21 The MOX fuel power, though, is
22 representative of much of the fresh fuel in the core.
23 So we are not giving it a break either. It's just not
24 the lead in the core.
25 DR. RANSOM: Jim, what were the slightly

1 shaded assemblies?

2 MR. ELLER: Okay. There are two locations

3 in the core that I tried to shade in -- Oh, oh.

4 DR. RANSOM: Not the MOX but the other

5 ones that are shaded.

6 MR. ELLER: Those are feed LEU.

7 DR. RANSOM: Feed?

8 MR. ELLER: Feed Westinghouse RFA, first

9 cycle fuel, fresh fuel. The ones that are not shaded

10 you see are fuel assemblies that are in their second

11 burn or in their third burn in this cycle.

12 DR. LEITCH: And B-12 and D-10 are the

13 locations for the NGF fuel?

14 MR. ELLER: Yes, sir, that's correct.

15 Those fuel assemblies are neutronically -- In the work

16 that I do, the nuclear analysis work, those assemblies

17 are so similar neutronically to the dominant

18 Westinghouse RFA fuel that we do not model them as

19 unique assemblies.

20 That is based on analysis that was done at

21 the beginning of cycle 15, the previous cycle, where

22 it was shown that modeling the assembly, very exactly

23 or not, made no difference in the nuclear analysis

24 work. Next slide, please.

25 This graphic is an attempt to represent

1 the lattice of the pin by pin lattice inside the MOX
2 assembly. I think it has been mentioned a time or two
3 that radially it is zoned radially across the lattice.
4 That means that the plutonium concentration in each in
5 varies as you move across the assembly radially.
6 The dark, solid circles in the corner are
7 MOX pins that have the lowest concentration of
8 plutonium. The gray, solid circles around the face of
9 the fuel assembly have an intermediate or middle
10 concentration of plutonium, and the open circles in
11 the center of the assembly are the highest
12 concentration of pins in the assembly.
13 The assembly is zoned so that, when you
14 place it in a core face adjacent to uranium fuel, you
15 can maintain a flat power distribution across the
16 assembly.
17 DR. LEITCH: So every rod in the assembly
18 is a MOX rod?
19 MR. ELLER: Yes, sir. The next slide is
20 a table of information where I have tried to show some
21 of the major core, the key core characteristics as the
22 cycle is depleted. The units of depletion here are
23 shown in effective full power days. The anticipated
24 cycle length is 515 days.
25 There is a column that shows the boron

1 letdown as the cycle depletes and the change in axial
2 offset as the cycle depletes. Then the fourth, fifth
3 and sixth columns give information about the power --
4 the peak power in the core on an assembly basis. That
5 would be the hottest assembly power in the core, the
6 hottest pin power in the core, and Fq is the hottest
7 spot on a pin in the core.
8 The final three columns show that same
9 type of power peaking information for the MOX fuel
10 assembly, and you can see throughout the burnup that
11 the MOX fuel assembly is held behind the leading LEU
12 fuel assembly.
13 The last row at the bottom of the table
14 shows the burnups on an assembly and pin basis, the
15 maximum in the core and the maximum that the MOX would
16 achieve in the first cycle of irradiation.
17 So in summary, the proposed core design
18 that would contain the MOX lead assemblies is
19 consistent with our current fuel management practices.
20 It places all four MOX assemblies in instrumented core
21 locations.
22 The MOX fuel duty is representative of
23 feed LEU fuel, but is not leading the core during
24 nominal depletion.
25 Based on preliminary analysis that we have

1 done with this core, we believe that the normal
2 operating limits and controls that we place on LEU
3 cores will provide sufficient margin to all of the MOX
4 specific design criteria. That is to say that the
5 normal control rod limitations and the normal power
6 maneuvering limitations and the normal axial offset
7 windows that we place on our plants should provide
8 adequate margin with the MOX fuel in the core. We
9 don't anticipate having to do anything extra.
10 There will be a lot of additional detailed
11 analysis that will occur in the summer and fall that
12 will clarify that before we actually load the core.
13 That's all I have.
14 DR. LEITCH: Do you anticipate any
15 additional operator training requirements or will this
16 basically be transparent to the operators?
17 MR. ELLER: There are additional training
18 that will go on. The design process at Duke involves
19 plant personnel very early in the process. We are
20 already engaged in that.
21 We are already providing data to the plant
22 simulator people that train operators, and even though
23 there's only four assemblies in the core, we want to
24 make sure that those simulators will work and, if
25 there's any impacts, there are -- the organization is

1 in place to pass that information along to the plant
2 folks.
3 DR. LEITCH: Do you have a position called
4 the reactor engineer?
5 MR. ELLER: Yes, sir. Our reload design
6 process has meetings all along the way. We have
7 already had two, and at each meeting more of the work
8 has taken place, and the reactor engineer is invited
9 to all of those. He has been to one of them in
10 person. He has been to the other one with a
11 conference call.
12 So those people are involved in every step
13 of the process.
14 DR. LEITCH: Is that an on-shift position
15 or is it day shift?
16 MR. ELLER: You are beyond me now.
17 MR. NESBIT: It is not a shift position.
18 It is in the engineering organization, but during
19 start-up type time frame, there is somebody from --
20 there's actually a whole reactor engineering group.
21 There's somebody there all the time from reactor
22 engineering.
23 CHAIRMAN POWERS: Any other questions for
24 the speaker? Thank you, sir.
25 Let me ask you if you can split your

1 presentation into two.

2 MR. NESBIT; Yes.

3 CHAIRMAN POWERS: Why don't we do that,

4 because what I fear is that, if we don't break pretty

5 exactly at one o'clock, this person won't get any

6 lunch, and he's hungry. So the rest of you, I don't

7 really care about.

8 MR. NESBIT: What I am going to suggest is

9 I think I can cover everything through LOCA before

10 lunch, and then we can finish up afterwards.

11 CHAIRMAN POWERS: Right, and I'm sure LOCA

12 will -- We want to allow lots of time for LOCA

13 discussion. Go ahead.

14 MR. NESBIT: I am Steve Nesbit, the MOX

15 fuel project manager for Duke Power, and -- next slide

16 -- I am not going to go through all the slides once

17 again, because I think some of the issues that aren't

18 controversial probably don't need to be treated. I

19 take at his word Dr. Powers' statement that the ACRS

20 can indeed read the slides themselves.

21 I've got my presentation broken into --

22 CHAIRMAN POWERS: Well, that may not be

23 100 percent true. We do have somebody from Tennessee.

24 MR. NESBIT: Maybe it is a 95 percent

25 I've got six different sections. I am going to first

1 talk about some of the lead assembly characteristics
2 that impact the safety and environmental evaluations
3 that we have done, talk about LOCA, talk about the
4 non-LOCA safety evaluations.
5 Then I am going to talk about the
6 radiological consequences or dose calculations from
7 the design basis accidents. I will talk about our
8 environmental evaluation, and then I will summarize.
9 Next slide.
10 The key MOX fuel lead assembly
11 characteristics that impact our evaluations are: To
12 begin with, mixed oxide fuel pellets, as has been
13 noted, are sintered ceramic oxide pellets similar to
14 low enriched uranium fuel. They contain about five
15 percent plutonium oxide and the remainder uranium
16 oxide. They have similar physical characteristics as
17 low enriched uranium.
18 George Meyer talked about the fuel
19 assembly design. I won't into that any further.
20 One key factor here. The MOX fuel decay
21 head is lower than the LEU fuel decay head, if you
22 compare a MOX fuel assembly with the same burnup to an
23 LEU fuel assembly with the same burnup during the time
24 frame of interest for transient and accident analyses.
25 Finally, we have shown that four MOX fuel

1 assemblies have very small impact on global core
2 physics parameters, things like moderator temperature
3 coefficients, etcetera, that are key factors in
4 accident analysis, and also on the core-wide
5 radionuclide inventories.
6 CHAIRMAN POWERS: That is something we
7 have not explored quantitatively today yet, but it was
8 brought up earlier today. If we radically alter,
9 hypothetically, the fission product release
10 characteristics of MOX for these four lead assemblies,
11 say multiplying them by 10, it really makes no
12 difference in an accident first term, does it?
13 MR. NESBIT: It doesn't, and we've got
14 some work that, I think, demonstrates that.
15 CHAIRMAN POWERS: I mean, you are working
16 with four out of roughly 200 assemblies now.
17 MR. NESBIT: Right.
18 CHAIRMAN POWERS: The four are located in
19 regions more centrally in the core early. So they are
20 more susceptible to damage, that it may not be --
21 making a four to 200 ratio is probably not quite
22 right, but still you can radically alter the -- Let's
23 say we used, say, a 1465 source term and made, say,
24 100 percent cesium release instead of 30 percent.
25 It's still --

1 MR. NESBIT: You ar still dominated by the
2 LEU fuel.
3 CHAIRMAN POWERS: Yes, everything is
4 dominated there, and we don't have -- So for the
5 purposes of lead test assembly, we are probably okay
6 just using LEU kind of release patterns here.
7 MR. NESBIT: Yes, but we did, in doing our
8 dose analyses, make some adjustments on the gap
9 fractions.
10 CHAIRMAN POWERS: Sure, that's right.
11 MR. NESBIT: And for the LOCA, the design
12 basis at Catawba is the TID 14844. So we just use
13 that. I think that would generally be considered.
14 DR. KRESS: I wonder if you can say the
15 same thing about the non-LOCA design basis accidents.
16 MR. NESBIT: We address those, and we can
17 say that -- Even if you assume that all of the damaged
18 assemblies in a non-LOCA event -- that all of the MOX
19 fuel assemblies are damaged in a non-LOCA event,
20 preferentially, which should not be the case since
21 they are not the leading assemblies, but even if you
22 assume that, the impact on the overall doses is
23 negligible.
24 DR. KRESS: Did you look at the potential
25 for reactivity insertion accidents that might fail the

1 steam generator tubes?

2 MR. NESBIT: Well, we looked at the

3 reactivity insertion accidents specifically, but we

4 did not -- Say, an RIA that causes a tube failure

5 would be a beyond design basis event that we don't

6 analyze.

7 DR. KRESS: Yes, that's right, it would

8 be. You're right.

9 MR. NESBIT: Next slide. Decay heat:

10 This is a SCALE calculation, a side by side, apples to

11 apples of MOX versus LEU, and it shows the ratio of

12 MOX to LEU. The key point there is that the crossover

13 of one at a value of one when MOX decay heat becomes

14 greater than LEU is approximately at three days, 70 to

15 80 hours.

16 So for the time frame of interest for

17 accidents, the MOX decay heat is lower. We just

18 assumed it was the same as the LEU decay heat.

19 DR. KRESS: These are results obtained

20 from ANS standards?

21 MR. NESBIT: This is from SCALE. This is

22 a SCALE calculation, ORNL code package.

23 DR. KRESS: Oh, SCALE is the name of the

24 code?

25 MR. NESBIT: Right. Well, it's the code

1 package. Now I think the ANS would give you -- and
2 actually, I'm not sure we have a slide on that, but we
3 did a similar evaluation for the ANS standard for the
4 LOCA calculation. It showed that the LEU curve
5 bounded the MOX decay heat curves, and we just used
6 LEU.
7 DR. KRESS: You didn't do that for spent
8 fuel pool cooling?
9 MR. NESBIT: For spent fuel pool cooling,
10 the impact of the MOX is --
11 DR. KRESS: Well, it's like two percent.
12 MR. NESBIT; Yes.
13 DR. KRESS: Hardly can see it.
14 MR. NESBIT; It is inconceivable that it
15 could impact the overall load on the spent fuel pool
16 with 1,000 assemblies or so. Next slide, please.
17 Thank you.
18 Global core physics parameters: When we
19 submitted our application, actually well prior to
20 that, we did a comparison of representative core
21 containing all LEU fuel, and then we extracted four
22 LEU assemblies and replaced them with MOX fuel
23 assemblies to give us an apples to apples comparison
24 of what that does to the physics parameters.
25 Now it's not the exact core that we are

1 currently planning on loading the MOX fuel in, but
2 that core design was not available at that time, and
3 the results would be similar.
4 As you can see, for the key parameters
5 that are used of interest in accident analyses, some
6 of which I have listed here, the changes are on the
7 order of zero to four percent or so. The bottom line
8 is that these are the same kind of changes we see from
9 cycle to cycle anyway, just due to core design change.
10 Next slide, please.
11 I didn't cover some of the other --
12 DR. BONACA: Just a second. So this, for
13 example, says the moderated temperature coefficient
14 would be slightly more negative.
15 MR. NESBIT: That's right. That's right,
16 which, depending on what scenario you are looking at,
17 is either good or bad. But the bottom line is it
18 doesn't move enough to be significant, and typically
19 we do bounding safety analyses with parameters that
20 bound these.
21 I didn't talk about the physical
22 characteristics like thermal connectivity, etcetera,
23 because those were covered in an earlier presentation.
24 Next I want to talk about the LOCA
25 analyses, and then I want to go to lunch. So let's

1 see how quickly we can get through here.

2 The approach that we used for the loss of

3 coolant accident analyses is that we did explicit

4 analyses of the response of the mixed oxide fuel

5 assemblies to a design basis LOCA. Now in many LTA

6 programs, that's not done. It is just -- You just

7 assume that the resident fuel analysis is bounding,

8 given the fact that you are not going to operate them

9 at the limiting power. But we went ahead and did an

10 explicit calculation for the MOX fuel assemblies.

11 We used the Framatome Appendix K model as

12 licensed, and then modified as necessary to address

13 mixed oxide fuel. That is a RELAP5/MOD2 based model.

14 We looked at the potential MOX fuel effects,

15 incorporated them as appropriate.

16 Next we did an apples to apples MOX to LEU

17 comparison calculation to see what difference things

18 made, and then we finally finished up by doing a

19 series of studies on burnup and axial peaking

20 location, etcetera, to establish a comprehensive set

21 of LOCA limits for the lead assemblies.

22 DR. RANSOM: That RELAP5/MOD2 -- that is

23 not S-RELAP5, Framatome's?

24 MR. NESBIT: It is the Framatome version

25 that is -- It's been around a while.

1 DR. RANSOM: It is the standard NRC
2 RELAP5/MOD2?
3 MR. NESBIT; Well, it's got some B&W mods
4 in there for Appendix K type calculations.
5 DR. RANSOM: Has that been approved for
6 licensing?
7 MR. NESBIT: It's been approved for a long
8 time. The next slide, please.
9 Here are some of the potential MOX fuel
10 effects that we looked at, and thermal conductivity.
11 We have talked about before. the impact is small. We
12 use the MOX specific thermal conductivity parameters,
13 volumetric heat capacity at the plutonium
14 concentrations we are talking about. Essentially,
15 there is not a difference relative to LEU. We used
16 the LEU values.
17 Decay heat -- we used the standard decay
18 heat curve after looking at it and verifying that the
19 value would be less for MOX.
20 We looked at a couple of nuclear related
21 parameters, void reactivity and delayed neutron
22 fraction. In both cases, the impact of any MOX
23 different, to the extent there would be one,would be
24 beneficial. More void reactivity and smaller delayed
25 neutron fraction would tend to quicken the decrease in

1 power following the initiation of the LOCA, and we
2 just used the LEU values for that as well.
3 CHAIRMAN POWERS: When you use the term
4 volumetric heat capacity, you are speaking of the core
5 as a whole or what does the term refer to?
6 MR. NESBIT: I think the term refers to
7 the actual model of the fuel pellet, fuel rod itself
8 in the hot channel. Is that --
9 Just come over here and sit. I imagine
10 this won't be the last time. Just sit over here.
11 CHAIRMAN POWERS: Would you identify
12 yourself also?
13 MR. DUNN: I'm sorry. My name is Burt
14 Dunn. I am an advisory engineer in lost coolant
15 accident safety analysis for Framatome, Areva now.
16 The term that Steve is referring to is
17 simply the density of the material times the specific
18 heat.
19 MR. NESBIT: I should probably clarify at
20 this time and follow up on something that Jim said.
21 At Duke we do mst of the core reload design ourselves
22 through methods that we have licensed with the NRC.
23 One thing that we don't do is the Appendix K LOCA
24 analyses. We rely on our vendor for that.
25 In the case of the MOX fuel, the vendor is

1 Framatome. So what I am talking about is analyses
2 that were performed by Framatome, and Burt is the
3 knowledgeable person there about this work.
4 CHAIRMAN POWERS: You mentioned the
5 volumetric heat capacity, and you said essentially
6 none. Then you used LEU. When we go back to the
7 slide, we see that indeed for the previous
8 presentation, indeed for the temperature range we're
9 talking about, that the LEU curve does form a lower
10 bound on the actual measurements for MOX.
11 MR. DUNN: Well, I think Patrick addressed
12 a little bit of that, sir, in terms of that curve was
13 developed from 20 percent plutonium, whereas the
14 analysis that we are doing here or the fuel that we
15 are going to load is about 4.5-5 percent.
16 MR. ELLER: It's five percent max.
17 MR. DUNN: So there is some difference in
18 there. The heat capacity itself, if it helps any at
19 all, would not be a strong actor for this reactor in
20 terms of lost coolant accident. The key item is the
21 balance of the decay heat versus the reflect cooling
22 mechanisms that occur.
23 So a few percent one way or the other
24 would not worry us. The recommendation from France is
25 to use -- There is a small adjustment for plutonium

1 concentration, but it is not very much.

2 MR. NESBIT: The other thing that I will

3 mention in terms of MOX effects, and I left it off the

4 Vu-graphs inadvertently, is really the big change that

5 we made -- that Framatome made to their evaluation

6 model to account for MOX is to use COPERNIC, the fuel

7 performance code that has recently been approved for

8 MOX and previously for uranium oxide, as the source of

9 the fuel temperature information, as opposed to -- I

10 think, the currently licensed Appendix K methodology

11 uses the TACO code, but COPERNIC is the code that has

12 the MOX models in it that have been reviewed and

13 approved now. So that was really the biggest change

14 to the evaluation model itself. Next slide. Thank

15 you.

16 The MOX fuel assembly radial zoning: As

17 Jim has just showed in his presentation, there's

18 actually three different plutonium concentrations in

19 the MOX fuel assembly, depending on which pin you are

20 talking about.

21 One of the things that Framatome did is

22 they looked at, well, what happens if you specifically

23 model each of the pins of the plutonium concentrations

24 versus just an average concentration? What they found

25 was that there really isn't an impact as you might

1 have expected, because it is driven by the power.
2 There is not an impact of the plutonium concentration
3 on the peak cladding temperature. Next slide.
4 The next thing we did was what I am going
5 to call a stylized MOX/LEU comparison. We said, okay,
6 let's take this --
7 DR. BONACA: Just a second, if I could ask
8 a question. We have a statement on page 9: No
9 significant impact of Pu concentration, because as you
10 said, the dominant effect is power. So, therefore,
11 the peak clad temperature still is in one of the UO_2
12 assemblies.
13 MR. NESBIT: In the calculation that
14 Framatome performed for us, they performed an
15 explicit calculation of the MOX fuel assembly and the
16 peak cladding temperature there. Then they modeled
17 the LEU fuel as the balance of the core.
18 Now what we have done -- and this is kind
19 of getting ahead, but what we have done at the end of
20 the day is we have established LOCA limits that will
21 ensure that the peak cladding temperature will be in
22 the LEU fuel per the LEU fuel analysis, which is the
23 analysis of record there being Westinghouse's SS LOCA
24 calculation for that fuel.
25 DR. BONACA: Okay.

1 MR. NESBIT: But I think that is going to
2 come out a little bit.
3 DR. BONACA: All right.
4 MR. NESBIT: Back on slide 10 here, the
5 stylized MOX/LEU comparison: We asked ourselves the
6 question, okay, let's just change one thing in this
7 model that we have now come up with that can do not
8 just LEU fuel but LEU fuel or MOX fuel. Let's just
9 change the fuel pellet characteristics and run a case
10 with the same conditions and see what difference it
11 makes.
12 As you can see, side by side LEU/MOX
13 comparison comes out to be within 40 degrees in terms
14 of peak cladding temperature. In terms of a LOCA
15 calculation, this is essentially the same answer.
16 Furthermore, I will add that this does not take credit
17 for some of the things that you could take credit for
18 in MOX base, like lower decay heat, the increased void
19 reactivity, etcetera. We are just trying to get a
20 calculation that is conservative and shows that we
21 meet our limits.
22 DR. BONACA: Those values probably are
23 reached during the blowdown, the heatup, the decay
24 heat.
25 MR. NESBIT; Let's go to the next slide.

1 That will show it.

2 There is the comparison in terms of peak

3 cladding temperature. As you can see, the peaks -- I

4 mean the traces are a virtual overlay, and the peaks

5 occur between 100 and 150 seconds.

6 CHAIRMAN POWERS: This temperature plot is

7 tracking the peak temperature of fuel rods in the MOX

8 assembly?

9 MR. NESBIT: Yes, and then running the

10 same calculation and changing that MOX assembly only

11 to make it LEU instead of MOX.

12 CHAIRMAN POWERS: And if I looked at which

13 rod was having the peak temperature in the MOX, does

14 would that change a lot or is it typically one rod

15 that's running hot?

16 MR. NESBIT: Well, I guess the question

17 you are getting to kind of gets to the power profile

18 across the MOX fuel assembly. It is fairly flat. The

19 effect of the radials only is to provide for a

20 reasonably flat power profile.

21 CHAIRMAN POWERS: So it might change quite

22 frequently, but it doesn't -- there is not a vast

23 difference.

24 MR. NESBIT; Yes. It might hop around

25 from rod to rod during the cycle, but it's not a big

1 difference between the rods.

2 CHAIRMAN POWERS: It's not one rod in the

3 first 20 seconds and another complete rod during the

4 next 20 seconds.

5 MR. NESBIT: Jim, do you think that is an

6 accurate characterization of the power profile?

7 MR. ELLER: We have moved from the

8 analyses that determined the peaking limits to LOCA

9 into the analysis that examined all the possible power

10 distributions that could exist in a core and verified

11 that all of them are lower than the limits that are

12 calculated by the LOCA evaluation model.

13 In the first burn in this fuel assembly,

14 the pin that has the smallest margin to the LOCA limit

15 is probably going to be either in the first row or

16 second row of the assembly throughout the entire

17 cycle.

18 I just summarized in a verbal fashion

19 thousands of cases that will be examined. So I can't

20 say with absolute certainty that it won't sneak to the

21 third row in on the assembly, but it is not jumping

22 all over the place.

23 This assembly will have burnable poison

24 fingers in every guide tube. So to have it jump next

25 to a guide tube or something like that, that's

1 probably not going to happen in this cycle.

2 MR. DUNN; If I might add, the LOCA model

3 is constructed purposefully to not try and position

4 the hot pin within the assembly, because of what you

5 said about it: Do these pins possibly moving around

6 here or there, the thousands of cases that Jim has to

7 study. The construction of the methodology is so that

8 we don't have to know where that pin is.

9 DR. RANSOM: That is just a hot rod

10 calculation that's done.

11 MR. DUNN; It is a hot rod calculation

12 with a generic simulation of the assembly around the

13 hot rod.

14 MR. NESBIT: Once we had satisfied

15 ourselves that there weren't any major MOX impacts out

16 there that would surprise us, we left the little

17 stylized comparison and went -- Framatome went to a

18 series of calculation that would determine the actual

19 limits for the fuels, and they performed what I am

20 calling sensitivity studies on things like the steam

21 generator design.

22 Catawba 1 and Catawba 2 have a different

23 design steam generator. So it does have an impact on

24 the accident response to see which one is worse; time-

25 in-life; location of axial peak; and also looked at

1 the end-of-cycle coolant temperature reduction that we
2 typically go through at our plants in order to squeeze
3 out as much power as we can from the core.
4 The result of all this work was a set of
5 LOCA limits for the core that is a function of axial
6 elevation and a function of burnup, and would ensure
7 that the peak cladding temperatures would remain below
8 the regulatory criterion of 2200, and also below the
9 resident fuel analysis temperature.
10 The actual values are provided in a letter
11 that we submitted to the NRC in response to additional
12 information, but I don't go through them here.
13 Next slide, Other Criteria and
14 Evaluations: We looked at all the criteria, not just
15 peak cladding temperature, maximum cladding oxidation,
16 hydrogen generation, coolable geometry, long-term
17 cooling.
18 Of course, they all met their limits well
19 within the regulatory limits that are established.
20 One thing that I will note was the maximum flow area
21 reduction due to ballooning was calculated to be 54
22 percent at the ruptured location, which is well below
23 90 percent, because that is an issue that has been
24 raised in conjunction with the accuracy of the LOCA
25 calculations.

1 We also looked at the impact of the MOX
2 fuel on the co-resident fuel, the analysis of record
3 for the Westinghouse fuel. Basically, the analysis of
4 record is still valid for the Westinghouse fuel, due
5 in large part to the fact that the overall assembly
6 pressure drop is very close between these two fuels.
7 Next I want to talk about some of the
8 issues that have been raised in conjunction with our
9 application by intervenors, and we have talked about
10 some already.
11 Fuel relocation during LOCA has been
12 identified as a Generic Safety Issue for LEU fuel back
13 in the 1980s, and it was dropped in 1998 by the NRC.
14 In october of last year IRSN, as you have already
15 heard, made a presentation on the PHEBUS tests that
16 they want to conduct, and they made some mention of
17 fuel relocation in connection with lost coolant
18 accidents and in connection with mixed oxide fuel.
19 One of the things they mentioned was
20 higher MOX power at end-of-cycle, and another thing
21 they mentioned was the so called filling ratio of a
22 balloon, and asked a question apparently, whether
23 there is a potential MOX agglomerates effect, and they
24 talked about the potential for bigger balloons or
25 blockage with modern alloys -- I put in "like M5."

1 I'm not sure they specifically mentioned that, but I
2 guess other alloys would be applicable here as well.
3 The intervenors have asserted that the NRC
4 should deny our application, because we haven't
5 adequately addressed these issues. I am going to
6 address them now, as we have also in our filings with
7 the Board.
8 MOX fuel relocation during LOCA: First of
9 all, there was confusion about -- in the IRSN
10 presentation about what is a LOCA effect and what is
11 a severe accident effect.
12 IRSN did note that there is a fuel
13 relocation at a lower temperature in the VERCORS RT2
14 test, which was done with mixed oxide fuel, than in a
15 similar VERCORS RT1 test that was performed with LEU
16 fuel. However, the salient point here is that that
17 relocation occurred at temperatures that are
18 consistent with severe accidents, elevated
19 temperatures on the order of 4000 to 4700 degrees
20 Fahrenheit, which is much higher than the fuel
21 temperatures that are experienced during a design
22 basis LOCA.
23 Second, we talked about the -- Jim talked
24 about the MOX fuel lead assembly power during the lead
25 assembly operation, his analysis of what the cycle is

1 like.

2 CHAIRMAN POWERS: Well, let's just be

3 clear. The RT tests are single pellet or small

4 numbers of pellets.

5 MR. NESBIT: Right.

6 CHAIRMAN POWERS: They are not talking

7 about the relocation that you would have in a LOCA.

8 MR. NESBIT: It's a different relocation.

9 It is a severe accident phenomenon, as I understand

10 it, prior to the onset of melting, and it is

11 potentially --

12 CHAIRMAN POWERS: Liquefaction, I think,

13 is the term that is used.

14 MR. NESBIT: But there was a confusion of

15 the phenomena that were at play there. There is a

16 real phenomena associated with LOCA called relocation,

17 and it is a real phenomenon. We acknowledge that.

18 MOX fuel lead assembly power is going to

19 be lower than the co-resident LEU fuel for the whole

20 cycle than the peak co-resident LEU fuels. So the

21 statement that apparently was made by IRSN may have

22 been applicable to some other kind of operation with

23 MOX fuel, but not to the operations that we are

24 planning for the Catawba cycles.

25 There is also some confusion there,

1 because there was no transcript made of that meeting,
2 and the Vu-graphs have certain information, but only
3 a certain amount of information. So it is difficult
4 sometimes to tell what was being meant by them.
5 There is no quantification made of this
6 postulated MOX agglomerate effect or, for that matter,
7 the LEU RIM effect, on the filling size. There is
8 really, as far as we have been able to tell, not any
9 substantial basis for saying that, even if relocation
10 is a phenomenon of concern, that MOX is going to be
11 significantly different, better or worse, than LEU
12 fuel.
13 Finally, I will note that the blockage due
14 to ballooning of M5 cladding was evaluated in our LOCA
15 model, and we evaluated it at the worst case
16 conditions, which is un-irradiated.
17 The assertions that the intervenors appear
18 to be making is that, because the M5 properties change
19 less with irradiation than Zircaloy, that that all of
20 a sudden is a bad thing and that we should be
21 penalized for that. In fact, that is one of the
22 attractive things about the M5 alloy, but we do
23 evaluate it specifically at the most limiting
24 condition, and evaluate the effects of ballooning and
25 found them to be acceptable.

1 CHAIRMAN POWERS: Can you remind me of
2 what our database is on M5 ballooning?
3 MR. NESBIT: I am going to have to ask
4 Burt to respond to that one.
5 MR. DUNN: The database for M5 ballooning
6 comes mostly from the EDGAR series of experiments
7 conducted in France, which are single pin tests,
8 pressurized, done in a steam atmosphere.
9 There are a total of -- I'm going to
10 guess. It is documented in -- The database that the
11 model has been constructed on is documented in the M5
12 topical report. I am going to guess that there is on
13 the order of about 150 data points included in there.
14 That facility has also been used to do
15 other cladding alloys, and so you can construct a
16 comparison to other experiments that have been done on
17 Zirc-4, for example.
18 CHAIRMAN POWERS: If I recall the
19 arguments that IRSN has made, they show that single
20 pin tests can either bound the amount of ballooning or
21 underestimate the amount of ballooning that you would
22 have in an array, depending on the particular
23 conditions that you have. Is that correct?
24 MR. NESBIT: I think that is their basis
25 for saying they want to look at this at Phebus where

1 they have multiple rods and they can assess that
2 impact.
3 MR. DUNN: They have talked about bundle
4 effects. I didn't know that they had talked about
5 individual pin strains, but rather maybe bundle
6 blockage effects.
7 CHAIRMAN POWERS: You are asking me to
8 speak from memory, and maybe I shouldn't. But my
9 recollection is of a slide that says when we compare
10 bundle tests to single pin tests, we find that in some
11 cases single pin tests will bound the amount of
12 ballooning. In other cases, they underestimate the
13 amount of ballooning.
14 MR. DUNN: Well, but the amount of strain
15 is quite -- I'll use the word stochastic in terms of
16 an individual test. It's all over the place. So I
17 would find that kind of an illegitimate statement. I
18 will say I wasn't at that meeting, and I was invited
19 and did not attend when some of that stuff -- In
20 retrospect, I should have been there.
21 CHAIRMAN POWERS: I wouldn't trust my
22 memory on the exact statement. Mr. Lyman would like
23 to have a note.
24 DR. LYMAN: No, just to clarify. I think
25 the issue was whether ballooning occurs at the same

1 height or at different heights in a bundle, and that
2 would lead to different blockage effects. If they all
3 occur at the same height, then you would have
4 constraints on ballooning from different rods, but if
5 they occur at different heights, then you might not
6 have those constraints.
7 MR. NESBIT; I think our fundamental
8 position on the ballooning issue is this. There's a
9 lot of interesting things you could look at with
10 respect to ballooning during a LOCA, and they have
11 proposed to look at some.
12 Fundamentally, the ballooning issue per se
13 is not a MOX issue. It is a LOCA issue. Now the
14 intervenors have attempted to tie it to MOX by
15 hypothesizing that there is a different impact on --
16 now we are going away from blockage; now we are
17 talking about fuel relocation, different filling size,
18 filling ratio, etcetera. It is a pretty tenuous
19 connection. But fundamentally, our position is that
20 the Appendix K LOCA analyses that we perform are
21 conservative, and there's a lot of reasons why they
22 are conservative.
23 You can always hypothesize that you want
24 to go look at something else, but we meet the current
25 licensing basis. We are confident the fuel will

1 perform adequately, even under the design basis loss
2 of coolant accident, and we think we have demonstrated
3 that with our evaluation models.
4 I guess, philosophically, I also have a
5 fundamental disagreement with the intervenors on the
6 point of their apparent belief that you must have
7 perfect certainty before you can execute a lead test
8 assembly program, and I mentioned this before. But I
9 think it is worth repeating.
10 Such a position would basically preclude
11 many of the fuel innovations the industry has put
12 forward over the past few decades.
13 CHAIRMAN POWERS: Well, in their defense
14 I haven't heard them actually say that.
15 MR. NESBIT: But that is the logical
16 conclusion that you come to from the arguments that
17 they have advanced, in my opinion.
18 One more slide on LOCA for now. To
19 summarize, we did perform the specific evaluations
20 with the models, as modified to address MOX fuel.
21 The analysis results were fundamentally
22 similar to uranium fuel, as shown by the stylized
23 side-by-side comparison. We did sensitivity studies
24 to bound the range of plant operating conditions and
25 establish the peaking criteria that MOX fuel remains

1 within 10 CFR 50.46.

2 Earlier today, you heard Ed Lyman mention

3 that MOX is inferior to LEU for LOCA. That statement

4 is not true. What we did, we did a stylized

5 comparison between MOX and LEU that showed that the

6 performance was virtually the same. In that

7 comparison, we didn't take credit for MOX benefits.

8 So there is no way you can draw the

9 conclusion that MOX is inferior to LEU out of that

10 comparison.

11 So that would be, I guess, where I would

12 propose to stop at this point.

13 CHAIRMAN POWERS: Any questions on this?

14 Otherwise, we are going to break for lunch, and we

15 will come back and Mr. Nesbit will be in the barrel

16 again.

17 MR. NESBIT: But not for long.

18 MR. CARUSO: I would like to make one

19 observation. I would like to ask people to sign in.

20 We have sign-in sheets that were not available this

21 morning. They are available on the table over here.

22 If you are present, please go and sign in. That is

23 the normal ACRS practice. I like to keep track of who

24 is attending the meetings. Thank you.

25 Actually, it is a requirement, but not all

1 Advisory Committee yet. So please sign in.

2 CHAIRMAN POWERS: With that, I will recess

3 us until 2:15.

4 (Whereupon, the foregoing matter went off

5 the record at 1:15 p.m.)

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1 A F T E R N O O N S E S S I O N

2 Time: 2:15 p.m.

3 CHAIRMAN POWERS: Let's come back into

4 session. I had an announcement to make, but it will

5 have to wait until more of the members are here. So

6 we will continue on with our Mr. Nesbit.

7 MR. NESBIT: When we last left our heroes,

8 we were talking about LOCA, and now we are moving to

9 the outline of the presentation of non-LOCA

10 evaluations. Next slide, please.

11 I am going to go quickly through these in

12 the interest of time. This slide talks about some of

13 the things, characteristics of our MOX fuel program

14 that render it benign with respect to non-LOCA events.

15 Generally, non-LOCA design basis events

16 are driven by the global core physics parameters like

17 MTC, etcetera, system thermal-hydraulic response, the

18 stored energy in the core, and the decay heat.

19 As we have noted before, the MOX fuel

20 impact on these parameters is typical of the kind of

21 -- four MOX fuel assemblies on these parameters is

22 typical of the kind of variations we see from cycle-

23 to-cycle. So generally our safety analyses use

24 bounding parameters that envelope the impacts of the

25 MOX fuel lead assemblies.

1 System thermal-hydraulics aren't affected
2 by mixed oxide fuel. Four mixed oxide fuel assemblies
3 have no appreciable impact on stored energy, and as we
4 noted before, the decay heat is lower in the time of
5 interest. So that is also bounding.
6 Some effects, however -- some events do
7 have effects that require some more specific
8 evaluation. I am going to add another thing, and that
9 is that Duke, obviously, does the cycle specific
10 evaluation of each reload to ensure that it is either
11 within the safety envelope or does reanalyses to
12 ensure that the safety criteria are met, and we are
13 very familiar for doing these for mixed core
14 situations, because we routinely have mixed core
15 situations at our plant.
16 We ran Mark-BW fuel from Framatome for
17 years and years. We transitioned to Westinghouse RFA,
18 and we still have a few Mark-BW assemblies -- At least
19 we recently had some Mark-BW assemblies in the
20 McGuire-Catawba plants. I'm not sure if we still do
21 have any at this point or not. So mixed core
22 analyses, transition core type things are not new to
23 us.
24 CHAIRMAN POWERS: Mr. Nesbit, may I
25 interrupt you to make one little announcement. Our

1 member from Tennessee asked for a correction. He
2 indicated it was not the written word he had troubles
3 with. It was that all the Yankees have such thick
4 accents, it's the spoken word he was having troubles
5 with.
6 MR. NESBIT: Well, I endorse Dr. Kress'
7 opinion there.
8 CHAIRMAN POWERS: Excuse me. I just felt
9 an obligation to make that clarification.
10 MR. KRESS: I'm glad you made that.
11 MR. NESBIT: Control rod
12 misoperation/steam line break: The bottom lien here
13 is that, basically, the limiting assemblies are under
14 control rods. I am going to again rely on the
15 committee to read these, but by not loading the MOX
16 assemblies under the control rods, it really precludes
17 these from being a concern for MOX.
18 Control rod ejection is the next overhead,
19 and again this is made a lot better by not loading the
20 mixed oxide fuel under control rods. However, there
21 is, obviously, the potential for a control rod
22 ejection accident to affect not just the assembly
23 under the control rod but other assemblies in the
24 vicinity; and given the fact that the Cabri tests have
25 indicated -- have looked at MOX fuel and particularly

1 Cabri Rep Na-7 tests experience a failure at about 125
2 calories per gram of an unusually energetic nature.
3 We felt like it was appropriate to do some
4 specific analyses here. What we have done is use the
5 SIMULATE-3K MOX code which Jim Eller spoke about
6 earlier to do a three-dimensional transient simulation
7 of the design basis rod ejection.
8 What we showed was that, even with very
9 conservative assumptions for things like rod worth,
10 etcetera, the maximum calorie per gram that we would
11 see in the MOX assembly is less than 50 calories per
12 gram, and well below any level at which you would
13 expect to see any adverse effects.
14 CHAIRMAN POWERS: Now as I remember, when
15 they look at the Cabri tests for sodium coolant and
16 try to apply them to light water reactor situations,
17 they make a correction in the energy at which you get
18 the fuel dispersal and what not, like that.
19 MR. NESBIT: There was a recent paper that
20 I read by Ralph Meyer in NRC Research that I think
21 tried to do that on kind of a global nature for all of
22 the rod ejection tests that had been performed, and I
23 think the conclusion from that paper was a curve of
24 energy versus oxidation -- yes, oxidation -- that
25 below which, once you had made all those corrections,

1 you could be sure that you are okay.

2 I think the values -- of course, it was a

3 curve. So there was not one value, but I think values

4 were on the order of 60 to 70 calories per gram there,

5 if I'm not mistaken.

6 CHAIRMAN POWERS: And that is not such a

7 huge margin above your 50 here, is it?

8 MR. NESBIT: It's not a huge margin, but

9 I will make a couple of points there. First of all,

10 I think that I would have to characterize that value

11 that Research recently published as a conservative

12 evaluation, trying to bound --

13 CHAIRMAN POWERS: So it is one of those

14 things that, if the value is 60 and you are 59.9, you

15 are in good shape. Is that what you're saying?

16 MR. NESBIT: I guess at this point, not

17 having studied it in a lot of detail, I guess I would

18 say I tend to agree with that.

19 CHAIRMAN POWERS: Well, maybe we'll just

20 chat with Dr. Meyer here and see what he has to say.

21 Why don't you just come over here and sit down. We

22 have a hot seat just for you.

23 DR. MEYER: I am Ralph Meyer from the

24 Office of Research at NRC.

25 The recent report was a research

1 information letter, and the adjustments we made with
2 our transient fuel rod code gave us an estimate of the
3 bias in the test data due to the atypical test
4 conditions.
5 The number that we would apply to the M5
6 cladding, which is very low corrosion, from that study
7 would have been 80 calories per gram, and this was an
8 enthalpy change. So you get to add another 16 to 18
9 calories per gram to bring it back into the ballpark
10 that you are talking about.
11 So I think there is a comfortable margin
12 there.
13 MR. NESBIT: We proposed an acceptance
14 criterion provisional for the lead assemblies of 100
15 total. So that does seem to be fairly consistent.
16 The other thing I will mention is that
17 again our evaluation was very conservative. If you
18 look at realistic rod worths for the McGuire-Catawba
19 cores as they are configured now, you don't even go
20 critical with these transients. So you don't really
21 have a transient.
22 CHAIRMAN POWERS: Thank you, Dr. Meyer.
23 MR. NESBIT: Next one, fuel assembly
24 misloading: The bottom line here is that the
25 administrative measures that protect against this for

1 LEU fuel are equally, if not more, useful for mixed
2 oxide fuel. So there is no special characteristic of
3 MOX that would make this any worse.
4 CHAIRMAN POWERS: In fact, what you say is
5 that a misload is far more readily detectable in the
6 case of MOX than it is in the case of LEU?
7 MR. NESBIT; Yes, for a couple of reasons.
8 One of the reasons we do our startup physics testing
9 and core flux maps is to detect an instance where we
10 might have misloaded the core.
11 In the instance of MOX, the actual thermal
12 flux in the location of the fuel assembly is markedly
13 lower than the thermal flux would be if there was an
14 LEU assembly there at the same power level. So if
15 there is a -- If you did switch out a MOX and an LEU
16 assembly, it ought to be readily apparent just from
17 the flux map.
18 The other, of course, is that we are going
19 to preferentially instrument the MOX assemblies, as
20 Jim Eller mentioned. So that further increases the
21 probability you could catch it at that point.
22 In summary for the non-LOCA accidents, we
23 have -- Most of them clearly have no MOX fuel impact
24 for MOX fuel lead assemblies simply by inspection, and
25 we evaluated the ones that would potentially have more

1 of a chance of having an impact and addressed them on
2 an accident specific basis.
3 Furthermore, as a part of the reload
4 design process we will go look at each one of these
5 accidents for all of the fuel that is proposed to be
6 in the core, and evaluate it specifically for that
7 cycle.
8 So next it brings me to radiological
9 consequences. We have discussed before that, when you
10 do radionuclide inventory analyses, generally you get
11 about the fission product inventories between MOX and
12 LEU fuel, but there are differences, in particular
13 with respect to -- One of the important dose --
14 important isotopes for accident calculations is iodine
15 131, and in a case where you look -- a bounding type
16 case, it would be as much as nine percent higher in a
17 MOX fuel assembly. It's kind of a function of whether
18 you look at it -- what burnup you look at it,
19 etcetera.
20 With that impact in mind, we looked at the
21 possible effect on thyroid doses and also total
22 effective dose equivalent.
23 As we have discussed earlier today,
24 accidents involving numerous fuel assemblies should
25 see no significant impact. We looked specifically at

1 LOCA, which affects 100 percent of the fuel in the
2 core, rod ejection which affects 50 percent per our
3 analysis assumptions, locked rotor, 11 percent.
4 What we showed is that, even addressing
5 just -- assuming that the MOX assemblies, all of them,
6 are in the failed population, the impact on the
7 overall dose that you would see is negligible and
8 still much less than the acceptance criteria.
9 I don't present those numbers here. They
10 are in the license amendment request and in the
11 associated RAI responses.
12 On the next slide we get to the more
13 interesting dose analyses, I guess I would say. Those
14 accidents that involve just one or a few assemblies
15 will see a bigger impact on a -- because the MOX is
16 either all or most of the population of failed
17 assemblies.
18 For our plant there's two accidents of
19 concern there. A fuel handling accident affects one,
20 and the weir gate drop affects seven fuel assemblies.
21 So we performed explicit calculations for these using
22 the approved alternate source term methodology for
23 Catawba and using MOX fuel specific radionuclide
24 inventories -- I would add, a very bounding
25 calculation of those -- and we did a sensitivity study

1 on the gap fraction; because one of the key aspects of
2 this analysis is how much fission gas is in the gap
3 that is available for release when the cladding is
4 breached.
5 What we did is increase the gap fraction
6 by 50 percent for the halogens and the noble gases
7 over the Reg Guide 1.183 values. As you might expect,
8 when you account for more iodine to begin with and
9 increase the gap fraction by 50 percent, you get, lo
10 and behold, an increase of about 60 percent for the
11 calculated doses, which sounds like a big increase,
12 but in reality in an absolute sense it is not, and it
13 is still within the regulatory limits.
14 The values for these I actually do present
15 on the next overhead.
16 Let's go to the summary for the
17 radiological consequences. There is a potential for
18 dose impacts even from just four lead assemblies, and
19 that comes from the radionuclide inventory
20 differences, the fission gas release.
21 The greatest impact is those accidents
22 that involve just a few assemblies. We did explicit
23 analyses of those. We put in place what we think is
24 a conservative treatment of the differences, and we
25 did indeed show higher consequences but well within

1 the limits.

2 So next we come to the environmental

3 evaluation, a subset of which is going to be a

4 discussion of severe accidents.

5 In most of the license amendment requests

6 we submit, we don't do an environmental evaluation,

7 because there is a categorical exclusion. But in this

8 one we felt like we should, and we did.

9 We provided an assessment of the potential

10 impacts of using four MOX fuel lead assemblies on the

11 environment. We looked at normal operations, showed

12 that there should be no impact on effluents, just a

13 very slight impact on occupational dose. That impact

14 would derive from the fact that the fresh MOX fuel

15 assemblies are slightly hotter than a fresh LEU fuel

16 assembly.

17 We looked at the accident situations,

18 which are already addressed in the safety analysis

19 section and in the radiological consequences. Next

20 slide, please.

21 So that left us with the potential impact

22 of beyond design basis accidents or severe accidents,

23 and we did also address these in the environmental

24 report.

25 We based our evaluation on work the

1 Department of Energy had done for the surplus
2 plutonium disposition and environmental impact
3 statement in which they looked at the impact of using
4 a 40 percent MOX core at Mcguire and Catawba.
5 They looked at four different beyond
6 design basis event sequences. They used MOX specific
7 radionuclide inventories, and what we did is we took
8 those results for 40 percent MOX score and just scaled
9 it back to a lead assembly core based on two percent
10 of the fuel instead of 40 percent being MOX.
11 There are some assumptions that go into
12 this calculation. First of all, we've got the MOX
13 assemblies separated by 90 degrees in the core, widely
14 dispersed, and we would assume that they would have no
15 impact on a progression of a severe accident or a
16 different progression of a severe accident. The DOE
17 assumed the same release fractions for LEU fuel as for
18 MOX fuel.
19 The results after you do the scaling
20 approaching is that you get a change in consequences
21 with four MOX fuel lead assemblies in a range of
22 between -0.2 percent and +0.7 percent, depending on
23 what figure of marriage you are looking at, early
24 fatalities, latent cancers, which scenario, etcetera.
25 There is another analysis that has been

1 done and documented on this done by Ed Lyman where he
2 did something that is similar in some aspects, and the
3 results of his evaluations were a change in
4 consequences once you scaled it from 40 percent MOX
5 down to four lead assemblies of up to 1.3 percent more
6 consequences, and that is early containment failure
7 scenario.
8 He also did a sensitivity study in which
9 he increased the actinide release fractions, and in
10 that he got as much as a 1.6 percent change. Next
11 slide.
12 CHAIRMAN POWERS: Your essential point
13 here is that, if you have four LTAs in a core, it
14 doesn't really matter what they do, inventory alone
15 dictates that they are not going to make a very big
16 impact.
17 MR. NESBIT: That is right.
18 CHAIRMAN POWERS: When we think of the
19 phenomenology itself, the key assumption is these LEU
20 release fractions are indicative of MOX release
21 fractions, and we are getting increasing evidence that
22 that is just not the case. Doesn't impact your
23 argument here, because you don't care -- I mean, you
24 can take wild, crazy numbers here, and you would have
25 the same conclusion roughly. I mean, your argument is

1 a one percent change is an indetectable change because
2 of the general level of uncertainty here.
3 MR. NESBIT: Right. In the next slide --
4 Let me go through that real briefly, because I think
5 I am going to address that point a little bit in the
6 next couple.
7 So the basis again for us is we are saying
8 there is not a significant change in core melt
9 probability. That is related to failures that are not
10 functions of the fuel, like equipment availability,
11 can you cool the core, have you changed the
12 fundamental design of the plant, etcetera.
13 We don't think there is a significant
14 change in severe accident progression, how the core
15 melts, so to speak, and what happens at that point on.
16 That is based on the fact that the physical
17 characteristics are similar, and the accident
18 progression, we think, is going to be driven by the
19 LEU fuel.
20 The next slide, radionuclide inventories:
21 Those are specifically addressed in the DOE and the
22 Lyman studies. Then that leaves you with source term
23 release fractions, and those have been addressed or
24 looked at by an expert panel, of which Dr. Powers and
25 Dr. Kress were a part, a couple of years ago.

1 I am not going to sit here and
2 characterize to you what you all said, because I think
3 you all could probably do a better job of it than me.
4 But there was a notation of potential for differences.
5 Whether those differences would ultimately be
6 significant or not, I don't think the work has been
7 done to determine that.
8 Generally, of the elicitations that were
9 performed, I think the results of the elicitations for
10 the MOX were similar to the results of the
11 elicitations for high burnup LEU fuel. In other
12 words, there was nothing that was off the world here.
13 I think another thing that the expert
14 panel did was they sort of brought to bear more recent
15 information in this area that had not -- information
16 that had been developed since the NUREG 1465 source
17 term came about, in the first place.
18 I note the VERCORS tests. There hasn't
19 been a lot of MOX specific tests in the severe
20 accident situation. An exception to that is the
21 VERCORS tests. It is our understanding there were two
22 tests performed at VERCORS with mixed oxide fuel, RT2
23 in an oxidizing environment and RT7 in a reducing
24 environment.
25 Both of them had somewhat analogous LEU

1 tests to compare to, and the information that we were
2 able to get out of the IRSN representatives and from
3 a later paper that was done on the RT2 tests is that
4 RT2 showed an earlier cesium release and a lower fuel
5 relocation temperature than the analogous LEU fuel
6 tests, and we got indications from IRSN that RT7 was
7 not -- didn't show the same trend and, in fact, RT7
8 apparently was more similar to LEU and may have had,
9 in fact, a higher fuel relocation temperature than
10 LEU.
11 I understand that NRC has that information
12 now. We don't, but in terms of the lead assembly
13 project I consider it to be interesting but not
14 necessarily relevant for the reasons that Dr. Powers
15 mentioned earlier.
16 In summary on severe accidents, the severe
17 accident behavior is going to be driven by the LEU
18 fuel, and any impact from the MOX lead assemblies is
19 going to be negligible when you compare this to the
20 overall uncertainties in light water reactor severe
21 accident behavior.
22 Here I guess I would like to cite some
23 examples in regulatory space. NRC authorizes uprates
24 all the time. Every time you authorize a power
25 uprate, you are authorizing a change in severe

1 accident consequences, just by the nature of what you
2 are doing and the change in radionuclide inventories.
3 I think that is -- The kind of power
4 uprates that have been authorized over the last years
5 are much greater in terms of potential for impact --
6 CHAIRMAN POWERS: Oh, you are a dirty guy.
7 You are hitting below the belt here.
8 MR. NESBIT: Sorry.
9 CHAIRMAN POWERS: Good point. Touche.
10 MR. NESBIT: Another example is changes
11 that most reactors have undergone in the last 10 to 20
12 years in which we have increased our cycle length from
13 annual cycles to 18-month cycles, in some cases 24-
14 month cycles. That would have a similar impact on
15 increasing radionuclide inventories and, therefore,
16 affecting severe accident consequences. But overall,
17 I would say that's been a very beneficial exercise for
18 the industry and for the performance of the plants.
19 I think I have said probably enough on
20 this subject right now. I guess I'll -- if there are
21 anymore questions on the severe accident, we can talk
22 about them.
23 CHAIRMAN POWERS: The only question that
24 comes promptly to my mind is -- suffers from the
25 charge of irrelevance. That is, in the course of

1 discussing MOX fuel in that expert panel you
2 mentioned, we became acquainted with some efforts
3 underway by IRSN to define an equivalent for NUREG
4 1465 source term. I wouldn't say equivalent -- a
5 similar source term.
6 They were drawing heavily on the VERCORS
7 and its antecedent tests, and they were, of course,
8 much more familiar with those tests than we are. They
9 were coming up with substantially higher release
10 fractions of some of the more refractory radionuclides
11 than we had ever seen anybody coming up with. Quite
12 frankly, I think -- Dr. Kress can correct me if he
13 thinks differently -- we were a little bit surprised
14 at some of the release fractions that they were coming
15 up with.
16 Though I think again we run into this four
17 LTAs in an ocean of LEU, it doesn't really matter what
18 you take as the fission part of release fraction, it
19 is an interesting thing.
20 MR. NESBIT: Right.
21 DR. KRESS: And it may have implications
22 for the 40 percent.
23 CHAIRMAN POWERS: Well, clearly, it does.
24 Now I think that RES is looking at that on its own,
25 and we will anxiously await what they come up with on

1 that, but that's just an interesting probably headache
2 that you have to confront.
3 MR. NESBIT: Yes, and we see that headache
4 out there. We don't think it is an insolvable
5 problem. I'm very interested to see what RES comes up
6 with, because they have access to the data, and we
7 don't. But I want to see what their work has to say
8 on this.
9 The other thing, I guess, I would add is
10 that, if you look at McGuire and Catawba as plants,
11 they are very far below the NRC safety goals, and if
12 you were to change -- Even if you were to change
13 severe accident consequences dramatically as a result
14 of release fractions for 40 percent MOX core, which I
15 don't think is where we are going to be at the end of
16 the day, but if we were to end up there, they would
17 still be well below the NRC safety goal.
18 CHAIRMAN POWERS: Well, some of us are
19 willing to challenge you on that, whether they are
20 below the safety goals or not, but that again suffers
21 from irrelevance here.
22 MR. NESBIT: That is all I have to say
23 about the severe accident issue. Unless anyone else
24 has any questions on that one, I'll wrap up.
25 CHAIRMAN POWERS: Charge ahead. Oh,

1 Graham?

2 DR. LEITCH: Not specifically on that, but

3 just before you wrap up, I was curious. Apparently,

4 you are not using the new fuel storage vaults in the

5 MOX fuel.

6 MR. NESBIT: That is correct.

7 MR. LEITCH; I guess I was a little

8 confused why that was the case, and what is the impact

9 of that?

10 MR. NESBIT: There is no reason why we

11 can't from a technical perspective. From a security

12 perspective, it is our intent, once we receive the

13 fuel, to put it in the pool underwater as quickly as

14 possible.

15 DR. LEITCH: I guess the basis of my

16 question was what about receipt inspection?

17 MR. NESBIT: We are going to do that. We

18 won't use the -- but we won't leave the fuel in the

19 new fuel storage vaults as a consequence of that

20 receipt inspection.

21 DR. LEITCH: So there is no compromise to

22 your receipt inspection?

23 MR. NESBIT: No. We don't see any reason

24 why there should be. I mean, we could still -- The

25 new fuel storage vaults are quite capable of handling

1 the MOX fuel from a criticality perspective. We could
2 still use them to lower the fuel into and then
3 retrieve them out of for new fuel inspection, if we
4 chose to do it that way, but we wouldn't unhook it
5 from the crane and leave it there.
6 DR. LEITCH; Okay, thanks. I understand.
7 MR. NESBIT: I guess I am ready to wrap
8 up. Actually, that was a while ago, but we've got a
9 slide here that I call "The Big Picture," and again
10 this is just to try to bring us back to what this
11 particular application really is, and I think I'm
12 telling --
13 CHAIRMAN POWERS: Before you go into your
14 first point, I will give you an anecdote. Professor
15 Apostolakis on this committee once suggested to
16 Shirley Jackson your first point, and she beat him
17 roundly around the head and the ears.
18 MR. NESBIT: She is not here now.
19 CHAIRMAN POWERS: And she is not here
20 anymore. As a caution about your first point.
21 DR. KRESS: Some words like "don't hand me
22 that old saw."
23 CHAIRMAN POWERS: Now did I help your
24 presentation?
25 MR. NESBIT: But I am going to make that

1 point. Sorry. The fact is there is plutonium in our
2 cores. There's plutonium in all power reactor cores,
3 and the amount that we are adding with four lead
4 assemblies is not an inordinate amount compared to
5 what is already there.
6 The other point, second sub-bullet down
7 there which I found kind of interesting when I
8 actually confirmed it with Jim and his nuclear
9 analyses, is that at the end of our cycles, 18-month
10 cycles with increasing burnup on our fuel, we are
11 getting 50 percent of our core power from plutonium,
12 and on a fuel assembly basis a lot more from some of
13 the twice and thrice burned assemblies.
14 A similar MOX fuel lead assembly program
15 was executed at Ginna in the early 1980s. It is not
16 the first time this has been done here. At Ginna,
17 which is a very small core with 121 assemblies, they
18 were actually 3.3 percent of the core with their four
19 MOX fuel assemblies.
20 The point that Mr. Blanpain made earlier,
21 I'll just reiterate. This has been going on for years
22 and years in Europe. There's currently more than 30
23 reactors in four countries using substantial
24 quantities of mixed oxide fuel. What we are talking
25 about doing is four assemblies out of 193, about two

1 percent.

2 So it is easy to get caught up in the

3 interesting nuances of differences between MOX and LEU

4 and what it might or might not mean, but fundamentally

5 what we think we have shown in our application is that

6 we can use mixed oxide fuel safely and ensure that the

7 health and safety of the public is protected.

8 CHAIRMAN POWERS: Do members have any

9 questions? Vic?

10 DR. RANSOM: I was wondering if some of

11 the intervenor's troubles with this are a fear that in

12 time you are going to go to much higher loadings.

13 MR. NESBIT: Higher than 40 percent or

14 higher than two percent?

15 DR. RANSOM: Well, higher than two

16 percent. I guess the Europeans have gone to 40

17 percent. Right?

18 MR. NESBIT: I'm not going to speak for

19 them. I'm sure they will speak for themselves. My

20 suspicion is that their position is that any percent

21 is too much.

22 DR. RANSOM: What are the plans in the

23 U.S.? Is that known?

24 MR. NESBIT: The plans in the U.S. are,

25 once the mixed oxide fuel fabrication facility is

1 constructed and is operating at the Savannah River
2 site, to start loading mixed oxide fuel at both the
3 McGuire and Catawba reactors.
4 We would gradually build up to, our
5 current plans are, about 40 percent MOX fuel core
6 fractions. Of course, that is contingent on a
7 successful license amendment request for batch use of
8 mixed oxide fuel and any conditions or agreements that
9 we reach with the NRC concerning core loading limits
10 there.
11 DR. RANSOM: Is that level driven by a
12 desire to burn up the excess plutonium or --
13 MR. NESBIT: Yes. It is a combination of
14 a desire to do it in an expeditious manner and a
15 desire to keep the plant characteristics reasonably
16 close to their current characteristics with LEU fuel,
17 because when you go to those higher core fractions,
18 the statements that I made earlier about negligible
19 changes to global physics parameters don't hold
20 anymore.
21 Our preliminary looks indicate that the
22 kind of changes we are talking about are still within
23 our safety envelope and don't pose a problem, but that
24 doesn't mean you can just keep pulling the string
25 indefinitely.

1 CHAIRMAN POWERS: Any other questions?
2 Well, thank you, Mr. Nesbit.
3 At this point, Bob Martin, I guess you are
4 back on. There you are. I will remind the members
5 that we do have this subject on the agenda for our May
6 ACRS meeting, and that we need to think about what
7 should be presented to the full Committee, what we
8 hear.
9 We have heard from the applicant, and we
10 are going to hear now from the staff on this subject,
11 and it has to be some mix of that, and the question is
12 what mix to have. We have scheduled two hours for
13 this presentation, or I should say Dr. Bonaca has
14 graciously consented to give us a full two hours on
15 this subject.
16 Well, Bob, you've got a powerful team
17 here. We are ready.
18 MR. MARTIN: I am Bob Martin. I know we
19 have an agenda item here on the review process itself.
20 With respect to the safety evaluation, the
21 radiological safety evaluation I would note two
22 aspects about it.
23 It is a review of the application
24 information submitted by the licensee for an amendment
25 to the operating license. To that extent, the review

1 process, the staff's review process, was much like it
2 is for any other license amendment application.
3 We reviewed the licensee's proposal
4 against the requirements of the regulations for an
5 operating license amendment. We requested the
6 licensee to provide information on, in addition to the
7 original application, a lot of the supplementary
8 information on design basis accidents and transients
9 and their consequences.
10 The nature of the MOX review leads us to
11 bring staff members to the table today in what I will
12 call two functional areas. One is reactor systems
13 areas, and the other one is radiological dose
14 consequences areas.
15 We have Ralph Meyer who has already spoken
16 today -- he has been introduced -- Undine Shoop,
17 Reactor Systems Branch, Mr. Ralph Landry, and then for
18 dose consequences area Mr. Steve LaVie.
19 With that, I would note administratively,
20 we have two slide packages here. Mrs. Shoop will
21 speak first. So that is one package, and then we will
22 go into the other presentations, and that one is in --
23 Mr. Landry's and Mr. LaVie's will be in the second
24 package.
25 CHAIRMAN POWERS: My understanding is you

1 are requesting a letter from the ACRS on this.

2 MR. MARTIN; Yes. Yes, I believe that is

3 the understanding. And to your earlier point about

4 what we would do for the full Committee, we are, of

5 course, meeting with the licensee on Friday. We will

6 get as much information as we can there.

7 Of course, if we can, we will solve the

8 problem there. If we can't, we will figure out what

9 the next step is. We will have our eye on how we can

10 communicate to the Committee where we are as soon

11 after that as we can.

12 CHAIRMAN POWERS: I think it is still

13 worthwhile -- Even if the Friday meeting does not

14 yield your most optimistic outcome, it's still

15 worthwhile to communicate to the Committee just to get

16 the rest of the Committee up to speed on this issue.

17 Most of the members have seen nothing.

18 I mean, all they have heard are rumblings

19 in the background on this particular issue. A more

20 optimistic outcome is that we simply have to defer a

21 letter until you give us the -- we resolve whatever

22 issues exist, that's feasible to do.

23 MR. MARTIN: Okay.

24 CHAIRMAN POWERS: Because I think 99

25 percent of what we've discussed here is still

1 applicable in any case.

2 MR. MARTIN; I think that is a good plan.

3 DR. RANSOM: Is the licensee's application

4 -- is this for two percent or does it include

5 increasing in the future to like 40 percent?

6 MR. MARTIN: Two percent? I think, with

7 respect to that, you meant that the lead test

8 assemblies would constitute two percent of the core,

9 2.1 percent or thereabouts. This application is just

10 for the lead test assemblies.

11 I understand that plans, prospective

12 plans, are for the licensee to submit an application

13 for batch perhaps sometime later in 2005. We have not

14 seen that yet. That is just oral information of their

15 possible future plans.

16 MS. SHOOP: If I could add onto that -- is

17 this on? There was a request in the MOX fuel design

18 report put forth by Framatome to have that approved

19 both for LTAs and for batch loading. The staff

20 reviewed it and approved it for the LTAs, but has

21 deferred any opinion on batch for a future batch

22 application.

23 Thank you very much. My name is Undine

24 Shoop, and I am here to lead off the reactor systems

25 review of the LTA application.

1 Our purpose here today is to discuss --
2 Well, I don't know. I seem to have them out of order,
3 because actually I was going to say next that we are
4 going to be going over the thermal mechanical design,
5 the data collection, the nuclear design, the non-LOCA
6 transients, and then Ralph Landry will be finishing up
7 by discussing the LOCA transient analysis.
8 Actually, our administrative assistant
9 helped me with this. We knew that that would
10 challenge him.
11 Okay. I would like to start off by
12 talking about the thermal mechanical design, and I
13 broke the presentation up this way. That way it is
14 clear when I am transitioning from one subject to
15 another.
16 First of all, the lead test assembly: As
17 with all fuel designs, we are using the licensing
18 framework in SRP Section 4.2. Even though SRP Section
19 4.2 does not say what type of fuel it is applicable
20 for, most of the analysis that is in there is
21 applicable, and we would want to know the results of
22 all the analysis that is in the SRP Section 4.2 for
23 the MOX assemblies, in addition to the uranium
24 assemblies.
25 Now this is where it gets a little bit

1 tricky. Whereas, Duke put in the application for
2 using the LTAs, the actual design of the LTAs was
3 provided by Framatome in Topical Report BAW-10238,
4 which is the MOX fuel design report. That is where
5 the specific thermal mechanical fuel design analysis
6 was presented to the staff.
7 So I guess I am going to start off with,
8 backing up a little bit, the purpose of an LTA. The
9 purpose of an LTA is to gather data on fuel
10 performance. We base it on a production design, in
11 this case the Advanced Mark-BW, and before we put an
12 LTA into the core, we make sure it is pre-
13 characterized.
14 CHAIRMAN POWERS: Explain a little bit to
15 me. What do you mean by based on production design?
16 This particular LTA is being produced in an ad hoc
17 fashion in France. I mean, this is not a routine
18 production, day in and day out, going on in France.
19 MS. SHOOP: Okay. What I mean by "based
20 on a production design" is that the fuel design
21 itself, the number of grids it uses, where they are
22 located, the mixing vanes in the grids, the top
23 nozzle, bottom nozzle, all of that is the same as a
24 production fuel design.
25 CHAIRMAN POWERS: Oh, okay. So it is the

1 microscopic -- It's not what is inside the fuel rod.
2 It's what is outside the fuel rod.
3 MS. SHOOP: Exactly. So that it will
4 perform based on characteristics that we have about
5 known fuel assembly design.
6 When we pre-characterize it, we examine it
7 between the irradiation cycles and after it is
8 discharged. The information that we get from the LTA
9 is the basis for our improved fuel design and
10 analytical models.
11 In this case, you notice that sometimes
12 when we have an LTA, we go beyond what is approved,
13 especially in the coding area, because we don't
14 approve a code for a certain burnup until you have
15 data. How do you get data? You can only get data if
16 you test, and that is the purpose of the LTA.
17 I know. I was told not to show that
18 slide, and I forgot that I had it in my slide package.
19 So I apologize for that, because it is not in the
20 handout.
21 CHAIRMAN POWERS: Let me ask you a
22 question. Is there someplace a list of the data that
23 you would like to acquire from these LTAs?
24 MS. SHOOP: Absolutely, and that is in the
25 data collection portion of this presentation. So if

1 you could just hold your questions for a moment, I'll
2 be glad to go over all of that.
3 CHAIRMAN POWERS: All right. If you want
4 to be that way. I am patient.
5 MS. SHOOP: Can we have the next slide,
6 please. The objectives of SRP Section 4.2: It
7 outlines four objectives for fuel criteria.
8 One is that the fuel system is not damaged
9 as a result of normal operation and anticipated
10 operational occurrences.
11 Fuel system damage is never so severe as
12 to prevent control rod insertion when it is required.
13 The number of fuel rod failures is not
14 underestimated for postulated accidents, and
15 coolability is always maintained.
16 I derived those directly from the SRP.
17 So that is the basis of anytime we review
18 a fuel assembly thermal mechanical design. Now since
19 our design is contained in the MOX fuel design report,
20 if you go to the next slide, to give you a better
21 flavor for what the MOX fuel design report included,
22 it included MOX design consideration which went over
23 the MOX fuel characteristics.
24 It included a discussion on weapons grade
25 plutonium, which is both the isotopics and the

1 impurities. Then it had the full thermal mechanical
2 fuel assembly analysis.
3 As part of the review of the thermal
4 mechanical part of the proposed topical report, the
5 staff did go down to Framatome's offices and actually
6 look at the calculations to perform an audit. In
7 particular -- I know that this has been brought up --
8 there's a couple of places in the original topical
9 where they only provided data to 50 and not to 60. I
10 think it happened in about two instances.
11 So those, in particular, were reviewed,
12 and they provided -- If you look through the RAI
13 responses, they did provide that information as
14 supplemental information. So that that is all on the
15 record of what the fuel behaves out to 60.
16 They also provided in this document the
17 experience database, which was predominantly the
18 European experience. They also described their lead
19 assembly test program, what Dr. Powers is alluding to.
20 That describes all their PIEs.
21 Now because we say it is based on the
22 production design, the Advanced Mark-BW, there are a
23 couple of changes, though, to accommodate MOX fuel,
24 and these are actually all things that -- are just
25 things that you need to do in order to accommodate the

1 MOX.

2 One is that they have a longer fuel rod,
3 and that is to increase your plenum volume for the
4 fission gas. They are going to use the European dish
5 and chamfer design. The reason is because, with this
6 being built over in Europe, the pellet press machines
7 are set up for those design specifications. That is
8 not something that is going to change the behavior of
9 the fuel.

10 CHAIRMAN POWERS: Can you tell us what the
11 differences are? A European dish is one that you can
12 only eat with, with a for in the left hand, is it?

13 MS. SHOOP: Yes. I believe that it is --
14 and I can be corrected by my Framatome colleagues if
15 this is wrong. But it is in the depth and the flexing
16 of the dish an in the -- what do I want to call it? --
17 the angle of the chamfer.

18 CHAIRMAN POWERS: Yes. Are they bigger or
19 smaller?

20 MS. SHOOP: Actually, it wouldn't really
21 change the characteristics.

22 DR. BONACA: Somewhere I seem to have read
23 -- I think in the SER, wherever -- that the European
24 dish and chamfer design is capable of preventing the
25 hourglass of the -- of shaping of the pellet.

1 MS. SHOOP: Actually, that is the reason
2 that we have the dish in all of the pellets, both
3 uranium and MOX, and they will all include a dish. I
4 think the difference between the MOX and the uranium
5 is because you have different equipment that is
6 already set up, what ends up happening is you get that
7 dish from the pellet pressing.
8 DR. BONACA: That seems to be -- At least,
9 I read a claim that that was a better design for the
10 purpose of reducing the hourglass effect, and maybe I
11 misread it.
12 MS. SHOOP: That is actually the case, and
13 that the dish will help prevent the hourglass.
14 DR. BONACA: Okay.
15 MS. SHOOP: The other change was the 95
16 percent theoretical density. The Advanced Mark fuel
17 design is approved for a 96 percent theoretical
18 density, but the European database on MOX is a 95
19 percent theoretical density, and in order to be
20 consistent with the database, Framatome opted to use
21 the 95 percent theoretical density for the MOX fuel.
22 Then the obvious difference is that it is
23 going to use mixed oxide for fissile material, because
24 one of the things to note is, when we approved 10238,
25 it is approved with the condition that it is only for

1 MOX LTAs, and the Advanced Mark-BW was approved with
2 a condition that it is only good for uranium oxide
3 fuel.
4 DR. KRESS: So you still have a loop to
5 close then, using the two together?
6 MS. SHOOP: You would never use the two
7 together. If you used -- In a core assembly that
8 contained both the uranium and the MOX, you would have
9 the Advanced Mark-BW fuel design for the uranium fuel,
10 and you would have the Mark-BW/MOX1 assembly design
11 for the MOX.
12
13 DR. KRESS: So you would never use the two
14 together.
15 MS. SHOOP: You would never -- Yes, you
16 would never use the design of the Mark-BW/MOX1 for the
17 uranium, or vice versa.
18 Okay. Mixed oxide fuel: Well, I know we
19 have already gone over this. So this is kind of a
20 repeat, but basically the use of the depleted uranium
21 matrix with weapons grade plutonium.
22 The significance of the weapons grade
23 plutonium is that you have fewer absorber isotopes,
24 and you have an increased fissile isotope. That just
25 changes some of your characteristics. But overall, it

1 also has -- Because of those two characteristics of
2 the weapons grade plutonium, you have a lower
3 enrichment requirement to have a comparable
4 reactivity, because what they are doing with this fuel
5 design is they are making it reactivity equivalent.
6 That's what they are equivalencing.
7 CHAIRMAN POWERS: The previous speaker
8 made a point that all LEU fuel quickly becomes mixed
9 oxide fuel, and what you are saying here is, well,
10 that is only kind of true, that because of the
11 isotopes that this is different. Is that -- Am I
12 reading this correctly?
13 MS. SHOOP: That is correct. That has
14 been the staff's position since the beginning of this
15 fuel review, that this is a new fuel design, is a new
16 fuel type, and it is different because of the isotopic
17 mixture. Even reactor grade mixed oxide fuel is
18 reprocessed uranium spent fuel.
19 If you would like to see the reactivity
20 requirement, in Figure 3.5 of the mox fuel design
21 report they have a nice little chart that actually
22 shows that the reactivity of weapons grade is between
23 the reactivity of LEU and reactor grade, and that is
24 how they can say that the database is adequate.
25 Go on to gallium. Gallium, one of the

1 favorite topics: Why is it here? Well, it is used to
2 stabilize the plutonium when it is in the state that
3 you need it for the bombs. But why is it a problem?
4 Well, it has the potential to migrate to the cladding
5 and embrittle the cladding material.
6 Because of that, we remove it through
7 polishing, which they have already discussed as being
8 performed out at Los Alamos to get it down to the
9 appropriate levels.
10 Why the staff is okay with the reduced
11 levels: There are some Oak Ridge tests on gallium
12 migration. That test is actually testing two
13 different fuel compositions, one of which has been
14 treated and now has a 1.33 ppm gallium level. The
15 other one is untreated and has a 2.97 ppm gallium
16 level.
17 They put this material into the cladding,
18 which actually they used zirc for, because they did
19 not have access to M5, and they put it into the
20 advanced test reactor. They have the reports out to
21 40 gigawatt days, and so far no migration of the
22 gallium has been seen from the fuel to the cladding.
23 The staff will receive the 50 gigawatt day
24 report before the LTA gets to 50 gigawatts, and if
25 there is any migration that is shown in that report,

1 then the staff will review the issue, and it will be
2 reviewed well in advance of the LTA reaching that
3 burnup.
4 Because of the current results, we are
5 confident that a 30 ppb limit, which is much lower
6 than what has been tested in those Argonne tests, will
7 be appropriate for the plutonium feed material, and it
8 will be incorporated into the fuel specification.
9 DR. RANSOM: When you refer to polishing,
10 is that a chemical process for removing the gallium?
11 MS. SHOOP: They call it an aqueous
12 polishing, and because that is considered to be part
13 of the fabrication, I would have to actually ask my
14 colleagues from Framatome or from Los Alamos, if
15 anyone is here, to discuss that.
16 MR. MEYER: George Meyer. The material --
17 it goes through an aqueous polishing process, which
18 means it is dissolved and run through an ion exchange
19 column, and that removes the impurities or reduces
20 them to a very low level.
21 MS. SHOOP: Now I would like to move on to
22 the data collection portion of this presentation.
23 The purposes of the data collection
24 program is to be able to get neutronic data through
25 the startup physics testing and fuel behavior data

1 through the post irradiation exams or PIE. This
2 information is needed to support batch loading. So
3 this is information that they will need prior to doing
4 a batch submittal.
5 The reason why you need this information
6 is because it is a code check for the CASMO-
7 4/SIMULATE-3MOX and for the COPERNIC codes.
8 On the neutronic front, Duke has made a
9 commitment that two of the LTAs will be located in
10 core locations that are directly measured by moveable
11 in-core detectors for the first and second irradiation
12 cycles.
13 That will provide operating data so that
14 we can actually compare the actual measured data to
15 what CASMO-SIMULATE is predicting, which will give us
16 confidence that the CASMO-SIMULATE code is predicting
17 the appropriate information.
18 CHAIRMAN POWERS: You are talking about
19 your confidence. You are going to get some data. You
20 are going to have a code calculation. There is going
21 to be some discrepancy between the data and the code
22 calculation.
23 MS. SHOOP: That always happens.
24 CHAIRMAN POWERS: At what point do you say
25 -- I mean, how do you decide this code is okay or this

1 code is not okay? I mean, how accurate do these data
2 have to be?
3 MS. SHOOP: Well, they have already done
4 some benchmarking against data with the code. So what
5 I would expect is that the difference between the
6 measured and the predicted for the in-reactor should
7 fall within the range that the St. Laurent benchmark
8 did.
9 CHAIRMAN POWERS: You said here is the
10 discrepancy between the code and the data. That means
11 the data have to be a certain level of precision,
12 preferably accuracy, but I don't think you can pull
13 that. I mean, what do you do to tell them, oh, yeah,
14 this data will, in fact, give us that required
15 accuracy? Is that part of your responsibility or is
16 that just part of theirs?
17 MS. SHOOP: Okay. If I'm answering what
18 I think you are asking, and please tell me if I am not
19 answering exactly what you are asking, they will get
20 the data, and they will be able to compare it to the
21 code predictions.
22 When they do that, they can look at what
23 the uncertainty is and all the other things that are
24 in that data. They can then compare it to what the
25 code was able to predict for the St. Laurent data, and

1 also for the criticals that it was benchmarked
2 against.
3 I would expect that it should be -- the
4 uncertainty should be within the range of that data.
5 That way, they have a good correlation between saying
6 that the database that they have used to benchmark,
7 which was reactor grade MOX fuel, is appropriate for
8 weapons grade MOX fuel.
9 CHAIRMAN POWERS: I guess what I am
10 driving at is suppose they came in and said we are
11 going to get this LTA data, and it is going to have an
12 uncertainty twice as big as the discrepancy between
13 the code calculation and the St. Laurent data.
14 Would that be a basis for you saying, no,
15 no, you're not going to put this LTA in this reactor;
16 it is not worthwhile, because the data is -- If the
17 uncertainty in the data is bigger than the discrepancy
18 you are looking for, you are not going to be able to
19 say anything.
20 MS. SHOOP: Absolutely. If the
21 discrepancy was that large, I think the staff would
22 have to start a dialogue with Duke so that we could
23 resolve the issue. Does that answer your question?
24 DR. TRIAFOROS: Are you planning on
25 reducing the -- or defy them and use them for

1 refabrication now or in the long run?

2 MS. SHOOP: For the LTAs, we are not. If

3 they come in with a batch application, and that's a

4 big "if," because we don't have one, so that is

5 speculative at this point -- we would then do staff

6 confirmation studies.

7 CHAIRMAN POWERS: One of the things that

8 we noticed, and maybe, Bill, you are the one to bring

9 this up, is that in most cases in the SER, especially

10 in the neutronics area, you reviewed and did not seem

11 to do independent calculations of the neutronics. Is

12 that a fair characterization?

13 MS. SHOOP: That's a fair

14 characterization. We did a data review of what other

15 people have said, and we used our own engineering

16 judgment to confirm that we believe that that data is

17 accurate.

18 If I could go on to the neutronic: Duke

19 has committed to the NRC to continue using the start-

20 up physics test plan that they already committed to

21 using previously. If this testing plan is consistent

22 with the ANS 19.6 standard on PWR start-up physics

23 testing, what it entails is critical boron

24 concentration, isothermal temperature coefficient,

25 bank worth measurements, low power flux map,

1 intermediate flux map, and the high power flux map.

2 Duke has also committed that, when they

3 take these measurements, especially like the

4 intermediate flux map, they will take it at

5 approximately the same power every single time. That

6 way, you can actually correlate what you get from one

7 cycle to the other cycle.

8 Then the other testing that we have is our

9 poolside post irradiation exam. First, you have the

10 examinations that are performed between cycles,

11 between the second and the second, the second and the

12 third.

13 You would do the visual inspection of both

14 the fuel assembly and fuel rods, fuel assembly growth,

15 fuel rod growth and the fuel assembly bow, because you

16 want to confirm that all of that is good before you

17 put it back in the reactor.

18 Then after you discharge the assembly,

19 which would be after the second cycle and after the

20 third cycle, you would have -- you would test your

21 grid width, your fuel rod oxide thickness, grid oxide

22 thickness, RCCA drag force, guide thimble plug gauge,

23 and the water channels, which is a test for the fuel

24 rod bowing.

25 CHAIRMAN POWERS: Would you define the

1 acronym -- the initials RCCA?

2 MS. SHOOP: Rod control cluster assembly.

3 It is basically making sure that your rods can get in,

4 in the time that they are supposed to get in.

5 Then after the fuel has cooled in the

6 spent fuel pool and it is at a level that you can send

7 it off to a hot cell, hot cell will be performed.

8 To correct the record, in our discussions

9 previously with Framatome and Duke and in the RIA

10 letter of March 1st on the BAW-10238, we had discussed

11 that we agreed that if the third cycle was actually --

12 if the LTAs were used for a third cycle, they would

13 complete the hot cell PIE for that fuel assembly, so

14 that it would be done.

15 What they will be testing in the hot cell

16 is the rod puncture which is for the fission gas

17 releasing composition, the metallography and

18 ceramography, which they would use eight clad samples

19 and eight fuel samples to look at the oxidation in the

20 hydrides, and the structure of the plutonium

21 agglomerates.

22 They will also do the cladding mechanical

23 tests, which is looking for ductility. They would do

24 burnup analysis which is to confirm core power

25 density, and they will use gamma scanning to do that.

1 They will also look at the burnup distribution, and
2 they will use two transverse fuel sections to compare
3 that to the prediction.
4 CHAIRMAN POWERS: The metallography and
5 the ceramography, will they -- what kind of
6 magnifications will they go to?
7 MS. SHOOP: That was not provided. I
8 believe that they will use what Oak Ridge is capable
9 of doing.
10 CHAIRMAN POWERS: Oak Ridge is capable of
11 a lot of things. In fact, it is one of the more
12 magnificent laboratories in the United States, is my
13 understanding without personal experience.
14 No, my question really is whether we get
15 information on intragranular fission bubbles or not.
16 MS. SHOOP: Since what they are looking
17 for is the structure of the plutonium agglomerates, in
18 order to be able to see the structure you have to get
19 down to a level that you would also see the bubbles.
20 CHAIRMAN POWERS: You would go down to the
21 level that you would see intergranular bubbles, but
22 would you really go down to the intragranular bubble?
23 MS. SHOOP: Probably not.
24 CHAIRMAN POWERS: It would surprise me a
25 little bit if you went that deep. Too bad. That's

1 where all the fun is.

2 MS. SHOOP: We will suggest it to them.

3 DR. LEITCH: Can we consider this -- the

4 completion of this post irradiation examination a

5 prerequisite for batch loading or haven't we crossed

6 that bridge yet?

7 MS. SHOOP: We would consider that they

8 need this data in order to be able to support a batch

9 application, and we have that in our SE.

10 Now I would like to continue and go on to

11 the nuclear design properties. As we have stated a

12 lot of times, for the four LTAs with 189 other

13 assemblies it is going to have an insignificant impact

14 on your core-wide neutronic behavior.

15 CHAIRMAN POWERS: Is that true, even with

16 these other LTAs in there?

17 MS. SHOOP: I would like to make the

18 disclaimer that what we reviewed was the application

19 that was provided, and the application that was

20 provided said it would be four MOX LTAs in a RFA core.

21 No mention of the other LTAs was made. Therefore,

22 what we are providing you today is the staff's

23 evaluation of what we had.

24 MR. MARTIN: Orally, that is what Duke has

25 told us. That would be one of the agenda items,

1 obviously, we will get into on Friday.

2 CHAIRMAN POWERS: I mean, this is -- It

3 says -- I mean, it is a pretty bold statement. So I

4 wondered if we generalize here. She is not being led

5 down any primrose path here, try as I might.

6 MS. SHOOP: Okay. Now to go into the core

7 design. Duke is using a checkerboard pattern, which

8 means that your once burned is next year's new fuel.

9 So you don't have new fuel base adjacent to new fuel.

10 What they have promised is that the LTAs

11 will be in symmetric core locations, and that during

12 the first cycle the LTAs will not be in rodded

13 locations. Therefore, they are not taking away from

14 the rod worth.

15 The LTAs will also not be limiting, but

16 they will be in prototypical locations, because the

17 last thing we would want to do is to have the LTAs be

18 in a place where they don't see a lot of flux, and

19 then find out that there's problems later. That's why

20 we encourage prototypical locations.

21 CHAIRMAN POWERS: You are not limiting the

22 fact that you could have problems later, because you

23 are not putting them in rodded locations, and you are

24 not putting them in lead locations. Yet in a full

25 load, they could be in lead locations.

1 MS. SHOOP: The purpose of the LTA is to
2 be able to compare it to be able to determine whether
3 or not the European experience database is applicable
4 to weapons grade. Where they are going to be located
5 right now will give us that, and it would give us that
6 confidence, and the European database does have MOX
7 fuel in rodded locations.
8 Duke as part of their application
9 performed some core sensitivity studies. They
10 performed studies in an all-LEU core and then they
11 performed a study that had all LEU with four MOX
12 assemblies.
13 They used the CASMO4/SIMULATE3/MOX code
14 suite in order to be able to perform these, and they
15 investigated the important core parameters. In
16 particular, you can see the key core-wide physics
17 parameters which are the critical boron concentration,
18 the control rod worths, the moderator effect, and the
19 fuel temperature coefficient.
20 They actually told me to use slides, and
21 it would have been better if they had told me just to
22 use, you know, the PowerPoint presentation, but they
23 didn't let me know that in advance. So you are going
24 to have to kind of spread out your handout, because
25 charts, slides 6, 7 and 8 are actually the results of

1 these sensitivity studies.

2 What you notice in each case on these

3 handouts is that they have the Delta. If you actually

4 look at the Delta for all of these important core-wide

5 parameters, they are not changing very much, because

6 you are not going to see a significant effect from

7 four LTAs in a core this large on a core-wide basis,

8 and that's what those studies show.

9 Now if we could go to Slide 9, which

10 actually you also need your tables for, you can see

11 the assembly physics parameters. The important ones

12 are the reduced delayed neutrons which is on slide 8.

13 However, the LTA will not be rodded. So it will not

14 significantly reduce the rod worth of any rods in the

15 core.

16 It also has an increased void reactivity

17 effect, as the Duke people had already discussed. It

18 provides a larger negative reactivity insertion during

19 the LOCA event. So that is actually a positive.

20 The prompt neutron lifetime is also

21 slightly decreased, and that is on Slide 8, there

22 again not significantly.

23 So that's why I came up with my conclusion

24 that adding four LTAs to a core this large will have

25 an insignificant impact on the core parameters.

1 So now I would like to go to non-LOCA
2 transients. I would like to start off by saying that
3 this was a deterministic licensing application. So it
4 only addresses Chapter 15 transients. We did not
5 address any severe accidents beyond design basis.
6 They are all out of the realm of this licensing
7 application.
8 To perform the LOCA transients, Duke used
9 their normal reload process. Part of that process is
10 to design the core and then test it for all the
11 Chapter 15 accidents, and they confirmed that all the
12 physics parameters fall within the reference values
13 previously calculated.
14 If you look at Table 30-1 of the November
15 3rd RIA response from Duke, what you will see is in
16 that table they actually put for all their Chapter 15
17 analysis, what they actually use, because this is
18 deterministic. So they actually have the bounding
19 worst case parameters in there when they calculate it
20 even for LEU fuel.
21 So what they did was they looked, and they
22 said, okay, well, this is what we already use, is our
23 worst case; where does MOX fall? And they found that
24 actually MOX fell always within the envelope of what
25 they were already calculating. They did, however, do

1 look a little bit more at the transients that are most
2 affected by the physics.
3 Mr. Nesbit has already gone over these,
4 but it is control rod ejection, rod cluster control
5 assembly misoperation, the steam system piping
6 failure, and the fuel assembly misloading.
7 I also came up with little sheets on every
8 one of these. The core loading pattern for their
9 control rod ejection will preclude significant impact
10 of RIA. It is because the LTAs are in unrodded
11 locations, and the LTAs are also not close to fuel
12 assemblies having significant ejected control rod
13 worth.
14 When they actually did the core-wide
15 basis, they found the peak LEU enthalpy of 54 calories
16 per gram. They found the peak MOX enthalpy of 30
17 calories per gram. The maximum broad worth was 412
18 pcm.
19 As you can tell, the MOX is well below
20 anything that any test has shown as being problematic.
21 CHAIRMAN POWERS: Are these particular
22 results -- you just reviewed these. You did not use
23 your own codes to go calculate these enthalpy inputs?
24 MS. SHOOP: That is correct.
25 CHAIRMAN POWERS: There has been

1 controversy within the research program about the
2 calculation of these enthalpy inputs with various
3 codes.
4 MS. SHOOP: Yes.
5 CHAIRMAN POWERS: Would Research come up
6 with the same numbers or roughly the same numbers, if
7 they did these calculations?
8 MS. SHOOP: Actually, Research doesn't
9 have the capability, which is why we weren't able to
10 perform an audit of this calculation. The worst
11 control rod ejection, the worst LEU enthalpy is
12 actually found at end of cycle, and the NRC does not
13 have a depletion capability right now. Working on it.
14 DR. MEYER: Could I comment on that?
15 CHAIRMAN POWERS: Please.
16 DR. MEYER: WE actually are using the
17 PARKS code coupled with RELAP to analyze typical rod
18 ejection accidents. So we haven't analyzed the
19 Catawba, but we have done a rather substantial generic
20 study and looked at a -- looked at the relation
21 between the worth of the ejected control rod and the
22 peak fuel enthalpy change that you could cause by
23 that.
24 For -- I hope I can remember these
25 numbers. For control rod worth, it is around $1.50.

1 You get peak enthalpy changes on the order of 40
2 calories per gram. Let me look at Harold and see if
3 that's the right number. So they nodded yes.
4 So this is work we have done at
5 Brookhaven. It is summarized in the recent Research
6 Information Letter, and that is very consistent with
7 these numbers.
8 CHAIRMAN POWERS: I guess, should I send
9 a note off to our Research Review Committee that says
10 Research needs some enhanced capabilities here?
11 MS. SHOOP: Actually, the Office of NRR
12 has sent over a user need letter, and the Office of
13 Research is working on getting that capability.
14 CHAIRMAN POWERS: Would you be kind enough
15 to send us a copy of that user need letter?
16 MS. SHOOP: Sure.
17 CHAIRMAN POWERS: I mean, it is not a
18 criticism. It's just, if we don't have some
19 capabilities that we need, we ought to set about
20 getting them.
21 MS. SHOOP: Yes. That is a paper that we
22 wrote back in, I believe, the '99 time frame, and we
23 identified all the needs that -- all the information
24 that we would need in order to be able to effectively
25 review a MOX batch application.

1 CHAIRMAN POWERS: Yes. I mean, that's
2 when we are going to need it.
3 DR. MEYER; We are -- In the research
4 program, we are in fact working on that right now, and
5 we will be in the next year participating in a couple
6 of international MOX benchmark calculations.
7 CHAIRMAN POWERS: Very good. Very good.
8 MS. SHOOP: If we can go on to the rod
9 cluster control assembly misoperation accident:
10 Because the MOX LTAs are in unrodded locations during
11 the first cycle and in non-limiting locations, they
12 will not significantly impact this accident.
13 The reactivity of the MOX LTAs and the
14 control rod worth for any rodded LTA during the second
15 and third cycles will also be below the limiting
16 values. That is because the reactivity of the MOX will
17 decrease to such a level that it will not limit the
18 accident.
19 For the steam system piping failure, the
20 accident is performed with the most reactive rod stuck
21 out. The LTAs are unrodded. So they are not going to
22 impact the most reactive rods' worth. Duke has a
23 criteria that for this accident they incur no loss of
24 DNB margin. So there will be no fuel failure,
25 including in the MOX fuel assemblies.

1 CHAIRMAN POWERS: So their DNB margin is
2 always at least as great as it is in the LEU?
3 MS. SHOOP: Yes.
4 CHAIRMAN POWERS: And there is no -- it is
5 always at least that big?
6 MS. SHOOP: Their criteria for this
7 accident is that you have no loss of DNB margin.
8 CHAIRMAN POWERS: Tough people. Tough
9 guys.
10 MS. SHOOP: And my last slide is a fuel
11 assembly misloading accident. The administrative
12 measures that Duke already has in place are equally
13 effective for MOX as what they are for uranium fuel.
14 In addition to that, the core distribution
15 measurements -- When you look at the MOX fuel and you
16 look at the LEU, when you actually run the in-cores,
17 you are actually going to be able to detect if a MOX
18 is misloaded, because the reactivity is -- or not the
19 reactivity, but the parameters are different enough
20 that you would be able to readily detect it.
21 CHAIRMAN POWERS: That is the claim that
22 is made.
23 MS. SHOOP: Yes.
24 CHAIRMAN POWERS: And pretty good
25 arguments were made in that. Did you look at that in

1 any detail? You said, okay, here's the data I am
2 going to have, here is the uncertainty I am going to
3 have in that data, here is the noise I am going to
4 have. Could I, Undine, looking at this come to that
5 conclusion?
6 MS. SHOOP: We did not actually look at
7 that data, because that data has not been generated.
8 CHAIRMAN POWERS: No, no. But I mean the
9 hypothetical data.
10 MS. SHOOP: I believe that, based on the
11 parameters that they will be able to get out from the
12 in-cores that, yes, if we went down and did an audit
13 after they loaded the core and ran the in-cores, that
14 we would be able to detect that as well.
15 CHAIRMAN POWERS: And you are going to ask
16 them to misload a core so that you can do that?
17 MS. SHOOP: Sorry, I'm not allowed to make
18 that request.
19 Now I'd like to turn it over to Ralph
20 Landry to go over the LOCA transient.
21 MR. MARTIN: We would go to the second
22 package of slides and just flip past the first two,
23 and you will begin with Mr. Landry's presentation.
24 MR. LANDRY: I'm waiting for Vic to get
25 comfortable.

1 CHAIRMAN POWERS: No, don't wait for him
2 to get comfortable. We don't let our members get
3 comfortable. They are supposed to be on the edge of
4 their seats, anxious to pounce at the slightest
5 misstatement.
6 MR. LANDRY: My name is Ralph Landry -- I
7 hope that is not a misstatement -- from Reactor
8 Systems Branch in NRR. Today I would like to talk
9 about the review that we performed of the Catawba MOX
10 LTA LOCA.
11 To again give standard disclaimer number
12 one, this review is based on the understanding that
13 the core is going to be Westinghouse RFA fuel with
14 four MOX LTAs inserted in the core. That was the
15 analysis which we reviewed for the LOCA determination.
16 The discussion that I am going to present
17 covers a couple of areas with regard to LOCA. We have
18 to look at the analysis of record, the LOCA pertaining
19 particularly to Catawba, the effect that the resident
20 fuel has and the effect that the MOX LTA will have on
21 that analysis of record.
22 When we look at the MOX LTA, we also want
23 to look at LOCA effects specific to those bundles.
24 You have heard some information already today, both
25 from Ed Lyman and from Steve Nesbit, regarding LOCA

1 calculations which have been performed, and I would
2 like to go over what we reviewed on the staff and how
3 we arrived at our conclusions.
4 The analysis of record for Catawba is a
5 Westinghouse WCOBRA/TRAC/REALISTIC LOCA analysis. The
6 resident fuel assumed in that analysis was all
7 Westinghouse robust fuel assemblies.
8 There are going to be loaded into the core
9 four MOX LTAs which are Framatome ANP -- or I guess we
10 call it AREVA now -- Mark-BW/MOX1 or, as you heard
11 this morning, hydraulically identical Advanced MARK-BW
12 assembly design.
13 The analysis of record covers -- was done
14 to cover the RFA fuel and the Mark-BW fuel which was
15 resident in the core at the time that a transition was
16 being performed from the Framatome Mark-BW fuel to
17 Westinghouse RFA fuel. When Westinghouse performed
18 their analysis of record, they performed a sensitivity
19 study, one of which used a surrogate or a proxy
20 assembly design with a pressure drop that was
21 representative of the Mark-BW pressure drop.
22 That provided a sensitivity for the
23 analysis of record, the licensing analysis, which said
24 it would indeed cover the resident fuel, the Mark-BW
25 fuel and the RFA fuel.

1 The Mark-BW/MOX1 assembly, or the Advanced
2 Mark-BW assembly, has a pressure drop that is much
3 closer to the Westinghouse RFA assembly's pressure
4 drop than it is to the Mark-BW fuel assembly's
5 pressure drop.
6 CHAIRMAN POWERS: I'm going to have to
7 work on this one.
8 DR. KRESS: You are going to have to
9 explain to me how you use analysis surrogate to give
10 you the same pressure drop. Do you put a fake orifice
11 on the end or do you distribute it all along by
12 changing the Fl/D, the hot rod diameter, or what?
13 MR. LANDRY: The fuel vendors are very
14 sensitive to the exact nature of the mixing vanes,
15 etcetera, in their fuel assemblies, and they are
16 loathe to share with one another a great deal of
17 detail.
18 DR. KRESS: And I could envision a loss
19 coefficient for each one of them.
20 MR. LANDRY: Right. Now what I'm getting
21 to is when a core has only one fuel assembly in it, it
22 is very easy to do a LOCA analysis, because you know
23 the pressure drop, you know the flow characteristics,
24 the hydraulic characteristics of every assembly in
25 that core.

1 When a core contains fuel all from one
2 vendor, you can perform a LOCA analysis, because you
3 know the hydraulic characteristics of every assembly
4 in that core very precisely. When a core does not
5 contain fuel from only one vendor and the other
6 vendors don't care to share details with one another,
7 you have to find a way to represent the other person's
8 fuel.
9 The way in which that is done is to do
10 your hot rod calculation before the rest of the core,
11 determine what is an average pressure drop, an average
12 flow condition for the rest of the fuel where you have
13 taken the other vendor's fuel, assumed a hydraulic
14 condition, then imposed that on your own fuel so that
15 you end up with an aggregate hydraulic condition for
16 the remainder of the core.
17 This is the only way you can really do a
18 calculation when you don't have the exact data on the
19 other vendor's fuel.
20 What was done with the resident fuel by
21 Westinghouse when they did the licensing calculation
22 was to do a calculation for all of the RFA fuel, and
23 then make assumptions about the pressure drop for the
24 transitional fuel that was still in the core. That
25 imposed an average pressure drop on the remainder of

1 the core.

2 Now what Duke is coming in and saying is

3 that the Advanced Mark-BW fuel characteristics lie

4 between the characteristics of the RFA fuel and the

5 Mark-BW fuel which was used in that licensing

6 calculation of record.

7 So the calculation of record now is

8 encompassing the effect of having an RFA core and now

9 having four MOX assemblies in the core. Now that's

10 the first piece of the puzzle.

11 DR. RANSOM: Are these multi-dimensional

12 calculations like with COBRA/TRAC, so you have

13 multiple passages through the core or are you talking

14 about --

15 MR. LANDRY: Well, I am speaking in

16 general terms of how with a 1-D code -- well, with a

17 3-D code you could take into account three-dimensional

18 flow characteristics, but that information would

19 definitely not be shared from vendor to vendor.

20 DR. RANSOM: So the calculations you are

21 talking about are all 1-D representations of the core,

22 possibly parallel channels of the hot rod?

23 MR. LANDRY: Yes, sir.

24 DR. TRIAFOROS: So, Ralph, at some point

25 in time you anticipated that Catawba would be using --

1 or the study anticipated they would be using Mark-BW
2 fuel assemblies for the whole core? I'm trying to
3 find the rationale of having, if I understood it
4 correctly, a study, a base study that has all, if I
5 understood it correctly, Mark-BW fuel. What is the
6 rationale, because we know that the fuel probably is
7 not all Mark-BW?
8 MR. LANDRY: The understanding that we
9 have -- and Duke may want to correct this, if I state
10 this incorrectly. When the current LOCA analysis of
11 record was performed, Duke was transitioning Catawba
12 between Framatome fuel and all Westinghouse RFA fuel.
13 So there was at that point some RFA fuel
14 in the core. That is why the analysis of record was
15 performed for Westinghouse RFA fuel, to which Catawba
16 was transitioning, but with a sensitivity study for
17 the effect of the Mark-BW fuel which was already
18 present in the core. Is that clear?
19 They are going from Mark-BW to RFA, but
20 now they are going from RFA to include Advanced Mark-
21 BW. So the study which was performed in reality going
22 from Mark-BW to RFA encompasses the effect of going
23 from RFA to RFA plus Advanced Mark-BW.
24 There was a time in the old days, the good
25 old days, when cores were homogeneous in nature or

1 manufacture, and we didn't have these issues to deal
2 with. Now that we have heterogeneous designs in the
3 core, we have to deal with how do you --
4 CHAIRMAN POWERS: It's a little bit like
5 your telephone bill.
6 MR. LANDRY: How do you have an analysis
7 that encompasses all the different types of fuel that
8 you have in your core?
9 DR. RANSOM: Ralph, your second bullet,
10 the Mark-BW/MOX1 -- that's a different geometry of the
11 Mark-BW fuel?
12 MR. LANDRY: Yes. That is the fuel that
13 was discussed this morning by Framatome, which is also
14 called the Advanced Mark-BW assembly design.
15 Framatome explained this morning that what they are
16 doing is taking the Advanced Mark-BW assembly and
17 putting the MOX pellets into that assembly. It is
18 hydraulically identical to the Advanced Mark-BW
19 assembly, but we are calling it Mark-BW/MOX1 to not
20 confuse that issue any further.
21 The issue is perfectly clear right now.
22 DR. TRIAFOROS: Now you said, correctly
23 so, that a new fuel vendor doesn't know what the
24 pressure drop to the previous assembly's is, but you
25 do, however, because you have access to that

1 information. So have you done verification that all
2 this squares away ultimately, all these assumptions,
3 and is it a proper approach?
4 MR LANDRY: Yes. This has been done
5 repeatedly for a number of plants, and we accept this
6 approach.
7 DR. TRIAFOROS: In the SER there is the
8 statement. There are four differences between the
9 Advanced Mark-BW and Mark-BW/MOX1 fuel designs, and it
10 enumerates what they are. I'm not quite sure if I
11 understood you correctly. I understood that the Mark-
12 BW and Mark-BW and MOX1 -- they are identical, which
13 is not the case based on what we are reading here.
14 MR. LANDRY: Well, I am basing my
15 statement on what Framatome has said, what they said
16 this morning. I did not review that part of this
17 submittal.
18 MR. NESBIT: Can I offer a clarification?
19 CHAIRMAN POWERS: Please.
20 MR. NESBIT: First of all, I apologize for
21 the confusion engendered by these various fuel
22 assembly names. But let me review three that we are
23 talking about.
24 Mark-BW is the fuel that Duke began
25 loading in its reactors in the late 1980s. We

1 transitioned from Westinghouse fuel to the Mark-BW
2 fuel assembly design. We still have a few Mark-BW
3 assemblies around, a lot of them in the spent fuel
4 pool.
5 The difference between that design and
6 what we refer to as the Advanced Mark-BW design, which
7 is what the North Anna LTAs are and the batches that's
8 going into North Anna, is primarily the material of
9 the cladding and the presence of intermediate flow
10 mixing grids. There's other differences, because fuel
11 assembly designs evolve, but that is the big -- what
12 I'll say the big deal for the purpose of what we are
13 talking about now.
14 The MOX1 assembly design, the Advanced
15 Mark-BW/MOX1 that we are talking about using for the
16 MOX fuel, is structurally the same as the Advanced
17 Mark-Bw that's going in at North Anna, with the
18 exception of the fuel rod length.
19 The pellet material is different.
20 Obviously, it is MOX. But that is the evolution
21 there, if you will.
22 DR. BONACA: Also if I remember, the
23 springs are different, aren't they?
24 MR. NESBIT: The springs are different?
25 DR. TRIAFOROS: Springs. I thought that

1 the assembly shown here has lip springs on the nozzle.

2 MR. NESBIT: As far as the current

3 Framatome products, the Advanced Mark-BW and the Mark-

4 BW/MOX1 that will be the MOX lead assemblies, the

5 spring design is the same, I believe. I'm looking at

6 Framatome, but they are behind the pillar here.

7 DR. BONACA: Same as the old -- the

8 original? Okay. Okay.

9 MR. NESBIT: And just to either further

10 clarify or make it worse, I'm going to say something

11 else. I probably should sit down.

12 The Westinghouse RFA design, which is the

13 co-resident fuel, is very similar in terms of overall

14 pressure drop to the MOX lead assembly design. We

15 stated in our application it is within four percent.

16 The older Framatome design, the Mark-BW,

17 plain old Mark-BW, is different, because it doesn't

18 have the intermediate flow mixing grids.

19 MS. SHOOP: Actually, if I could

20 specifically address your comment, I see in here where

21 you are talking about the four differences on page 4

22 of the SER. Those four differences are the four

23 differences that I had on my slide 6 from the

24 presentation.

25 What Ralph is saying is that thermal

1 hydraulically the Advanced Mark-BW fuel design and the
2 Mark-BW/MOX1 fuel design are the same, because most of
3 these differences were just slight differences, and
4 most of these are actually to the pellet.
5 DR. TRIAFOROS: It talks also about the
6 difference in the dish and chamfer design.
7 MS. SHOOP: And those are both pellet
8 parameters. That will not change the thermal
9 hydraulics.
10 DR. TRIAFOROS: Yes, you are absolutely
11 right. Thank you.
12 MR. LANDRY: That deals with the analysis
13 of record, the licensing basis analysis.
14 Now you heard this morning from Framatome
15 and from Duke a discussion of a LOCA analysis which
16 was performed by Framatome, or AREVA, for the MOX LTA.
17 That analysis used the Framatome ANP Appendix K code,
18 RELAP5/MOD2-B&W, which is an approved Appendix K
19 model.
20 I've got to keep this straight. We are
21 now talking about a REALISTIC LOCA which is the
22 analysis of record, and we are now talking about an
23 Appendix K calculation which is the calculation for
24 the LTAs.
25 That approved modeling also includes the

1 M5 cladding properties.

2 CHAIRMAN POWERS: And can you give us a

3 thumbnail sketch of the cladding properties that are

4 approved that are used for this calculation?

5 MR. LANDRY: No. All I deal with is the

6 property tables.

7 CHAIRMAN POWERS: So we need to go look at

8 the M5 SER.

9 MR. LANDRY: Right.

10 CHAIRMAN POWERS: Thanks, Ralph.

11 MR. LANDRY: Well, you need to have

12 something to do tonight, Dana.

13 CHAIRMAN POWERS: That's right.

14 Otherwise, I would be wandering the streets. Right?

15 MR. LANDRY: You would get in trouble.

16 I'm doing this for your own good.

17 One of the things that we questioned,

18 because they were going to MOX, they were using

19 plutonium startup instead of LEU, was the decay heat

20 model itself.

21 You heard some discussion this morning

22 about the decay heat model. The model that has been

23 used by Framatome for this calculation is the

24 Framatome decay heat curve, which is approximately 1.2

25 times the 1994 ANS curve, which produces a majority of

1 its energy from the fission of plutonium for highly
2 burned fuel.
3 Now this curve also just happens to
4 encompass 1.2 times the 1971 decay heat curve. If I
5 can have the next figure -- I don't know if you are
6 going to be able to see that.
7 CHAIRMAN POWERS: We got it here. We can
8 see it.
9 MR. LANDRY: The upper curve is the
10 Framatome decay heat curve. The lowest curve is the
11 1994 curve, and you see one in between that
12 transitions back and forth between the two. That is
13 the 1971 decay heat curve times 1.2.
14 So we looked at this and said, okay, for
15 the LTA calculation -- this is an Appendix K
16 calculation anyway -- that Framatome curve is
17 definitely conservative. It bounds the '94 curve by
18 1.2. It bounds 1.2 times the '71 curve, and we agree
19 that for this purpose it should bound any decay heat
20 effects we see from a loading of plutonium.
21 In making that decision, I spent some time
22 one day with Virgil Schrock and talked with Norm
23 Lauben, our decay heat experts, and was assured that,
24 for the purpose of the large break LOCA, that curve is
25 adequate. It is going to bound the effect of

1 plutonium.

2 The ANS Subcommittee is looking at, and I

3 believe met this past January and discussed, the

4 effect of plutonium decay heat curve. So at this

5 point in time, this curve is a reasonably conservative

6 curve to use. It meets the requirements of Appendix

7 K. It is going to bound the effect of plutonium.

8 So we agree that, yes, indeed, they have

9 done acceptable analysis. Let me have the next one.

10 Now this morning you heard comparison

11 information being given of the MOX LTA predicted peak

12 clad temperature being 2018 degrees and the LEU peak

13 clad temperature being predicted at 1981 degrees.

14 As was stated, that is a calculation based

15 on using the Framatome Appendix K model to calculate

16 the LTA and then to substitute the properties of UO_2

17 in place of the plutonium to calculate an LEU number.

18 The licensing calculation of record states

19 that the limiting case PCT is 2056 degrees Fahrenheit,

20 meaning that the PCT now for the MOX using an Appendix

21 K calculation is 38 degrees lower.

22 Sometimes when we look at Appendix K

23 versus realistic, we say there should be a such and

24 such a difference between the two. Well, we have to

25 remember that we are looking at an Appendix K

1 calculation for an assembly in a non-limiting
2 location. We are now comparing that with a PCT for
3 the PCT of the highest value for the 95th percentile
4 realistic calculation.
5 Now the maximum LOCA oxidation predicted
6 for the MOX LTA is 4.5 percent versus 10 percent for
7 the resident fuel from the limiting case. As I said,
8 the MOX LTA placement is in a non-limiting location.
9 The next one, please.
10 The conclusion of the staff is that the
11 MOX LTAs will comply with the requirements of 10 CFR
12 50.46 when inserted into a core of Westinghouse RFA
13 LEU fuel.
14 CHAIRMAN POWERS: Any questions on this
15 analysis? You're going to get away Scott-free?
16 DR. KRESS: Well, I'll ask him a question.
17 CHAIRMAN POWERS: All right.
18 MR. LANDRY: Tom has never let me move
19 away from the table -- never.
20 DR. KRESS: It is my job. I was just
21 mulling over how do you make a correction of peak clad
22 temperature, which is a transient that involves heat
23 transfer coefficients and specific heats and thermal
24 conductivities and stored energies? What is it that
25 goes into making a correction to an LEU calculation to

1 get this difference in 38 degrees? Just exactly how
2 did they arrive at that? I don't understand what
3 corrections.
4 MR. LANDRY: I am not talking about
5 corrections with this. What I was simply comparing
6 was the predicted PCT for the MOX LTA when calculated
7 by an Appendix K model in a non-limiting location
8 versus a PCT predicted for the RFA assembly by its
9 licensing basis calculation.
10 DR. KRESS: Oh.
11 MR. LANDRY: I was simply -- This morning,
12 Tom, you were hearing the LEU versus LTA in the same
13 location by Appendix K, and I am looking at the
14 licensing limit at this point for Catawba Unit 1 is
15 2056 degrees Fahrenheit.
16 DR. KRESS: Thank you.
17 DR. RANSOM: You didn't do any independent
18 calculations, I guess, for a LOCA transient?
19 MR. LANDRY: No, we did not. We do have
20 the RELAP5/MOD2 B&W input model for Catawba. That has
21 been supplied to us, but we have not attempted to run
22 it. That is with the B&W modified version of
23 RELAP5/MOD2 which meets full Appendix K requirements.
24 We have not attempted to convert that deck
25 into a RELAP5/MOD3 form and try to run it yet. We

1 may--

2 DR. RANSOM: Do you have plans to do that?

3 MR. LANDRY: We may when we start

4 discussing batch loading at some point in the future.

5 But, of course, we would have to determine what

6 changes we were going to make to the decay heat model

7 and so on to perform the calculation. But we have the

8 deck --

9 DR. RANSOM: You plan on making Realistic

10 calculations, I guess, right now?

11 MR. LANDRY: Right. But we have the deck,

12 and we can run it, but we have to do some significant

13 conversions from the B&W version of RELAP5 to the

14 version that we have.

15 CHAIRMAN POWERS: Any other questions?

16 Then I am going to recess us until 20 after the hour.

17 (Whereupon, the foregoing matter went off

18 the record at 3:59 p.m. and went back on the record at

19 4:19 p.m.)

20 CHAIRMAN POWERS: Ralph, you left us

21 feeling inadequate. We hadn't interrogated you close

22 enough. So during the recess we got together and

23 decided a few other questions, so that you felt

24 fulfilled for the day.

25 MR. LANDRY: Well, I'm glad to hear that,

1 Dana, because I gave the answers then, too. I was at
2 the other end of the hall.
3 CHAIRMAN POWERS: Unfortunately, they
4 didn't quite make the record. So we are going to have
5 to have you repeat them.
6 The question came up. We have discussed
7 throughout the day a little bit about this relocation
8 during the LOCA. You didn't discuss that issue at
9 all. I guess two questions came to mind.
10 One is that, gee, this used to be a GSI.
11 How come it is not anymore, and if you knew why the
12 decision had been dropped.
13 The second is: Do you find anything about
14 the MOX fuel that would lead you think that any fuel
15 relocation during a LOCA would be different than for
16 LEU?
17 MR. LANDRY: First, I am not an expert on
18 the fuel. Ralph Meyer is. I don't know why it was
19 dropped. I defer those questions to him. But I would
20 say at this point that relocation is not considered in
21 Appendix K.
22 So this was an Appendix K calculation
23 which was performed for the MOX LTAs, and since it is
24 not required and not a part of Appendix K, one would
25 not expect to see it there.

1 CHAIRMAN POWERS: I think we understand
2 that. We just asked if you had given it any thought.
3 MR. LANDRY: Not at this stage, because of
4 the nature of these calculations. It is a part of
5 some vendors' models for Realistic LOCA, not all,
6 though. So if this was a complete core Realistic
7 model, then we would have to see how it was being
8 accounted for. I would refer the rest of the comments
9 over to Ralph Meyer.
10 DR. MEYER: I think that is essentially
11 the right answer, since --
12 CHAIRMAN POWERS: His is a legal answer.
13 The question we were asking that would go to you is a
14 phenomenological question. Do we see anything about
15 the fracturing during the operation of MOX fuel that
16 would suggest to us that it is different than the
17 fracturing of LEU fuel?
18 DR. MEYER: I can't answer the question,
19 because I don't think that we have seen any MOX fuels
20 being exposed to those conditions.
21 CHAIRMAN POWERS: These would be just
22 normal operational conditions.
23 DR. MEYER: Yes. I don't -- I really
24 don't think that is going to do it. I mean, we can
25 look at cross-sections of the microstructures of stuff

1 that's been through normal operation, but it seems to
2 come unglued when you balloon the rod.
3 The thing that -- I would like to go back
4 to Ralph's answer, though, because it is not a bad
5 answer. Since Appendix K was formulated in 1973, we
6 have recognized some really conservative features and
7 some non-conservative features.
8 This is one of the non-conservative
9 features that has been recognized and, in fact, one
10 that has been mentioned many times and forms the
11 basis, in fact, for resisting any changes to Appendix
12 K, because you don't want to just cherrypick and take
13 out the decay heat or the Baker-Just correlations that
14 are giving you the known conservative margins, which
15 are rather substantial.
16 So I think that you have an offsetting
17 situation where it isn't well quantified. It is under
18 study, and that is probably the best we can do right
19 now. You can make estimates using packing fractions
20 from rod studies and things like that, which have been
21 done, and they are in the order of magnitude of the
22 overconservatisms in some of these other features like
23 Baker-Just which gives you big temperature
24 differences.
25 CHAIRMAN POWERS: You say it is under

1 study. In what context is it under study?

2 DR. MEYER: Well, we have two experimental

3 programs which have fuel relocation as major

4 objectives. One of them is in the Halden reactor, and

5 one is in our program up at Argonne.

6 So at Argonne we are testing rods under

7 out of pile conditions with electrical furnace. It is

8 a radiant heating furnace. The heat conditions aren't

9 exactly right. So that gives you an incentive to go

10 in-reactor and do some checking.

11 So these have been closely coordinated

12 with four tests that are planned in the Halden

13 reactor. I think they are called EFA-650. These will

14 be about as close as we can ever come to a situation

15 where you have ballooned and rupture and heat up and

16 look for the relocation.

17 The interesting thing about those tests is

18 the relocation has to come at a very specific time or

19 it just doesn't matter. It has to come before quench.

20 So that is not a very big window, and all of the

21 rattling that goes on during quench, which might be

22 the cause of some observations that have been seen, or

23 the handling that takes place afterwards before you

24 get it to a hot zone, might be responsible for the

25 relocation.

1 I am not suggesting that this is a non-
2 effect, but what I am suggesting is that it is tricky.
3 At Halden, for example, we have two opportunities to
4 observe this. One is that they are installing some
5 fast responding neutron detectors through four axial
6 locations in the region where the balloon is expected,
7 to see if you can detect any change in the neutron
8 flux right after the rupture occurs.
9 The other thing is that we will look very
10 carefully at the balloon section to see if it is
11 oxidized more than you would expect it to be, based on
12 an analysis that did not assume relocation.
13 You know, if you can't detect that, then
14 it probably doesn't matter. So I would say that we
15 are on the verge of, first of all, trying to find out
16 if this effect is real, if it has an impact, and now
17 what you are talking about, would it be any different
18 for UO_2 and MOX?
19 That is just a little hard to imagine. I
20 mean, perhaps the packing fractions could be different
21 if there is a different distribution of particle
22 sizes, but this has got to be a second order effect,
23 I would think.
24 CHAIRMAN POWERS: Thank you.
25 DR. BONACA; There was another question

1 that was raised this morning regarding the effect of
2 surface treatment on embrittlement of Zircaloy,
3 niobium alloy.
4 DR. MEYER: This is a completely separate
5 question. This has to do with embrittlement, and the
6 embrittlement phenomena don't -- I don't think they
7 have any connection to what is inside the fuel. It
8 could be MOX. It could be UO_2. It could be anything.
9 The embrittling stuff comes from steam on
10 the outside. You oxidize. You absorb hydrogen, and
11 you go through a phase change. You have some
12 dimensional changes. You have oxygen diffusion. You
13 have hydrogen absorption, hydrogen precipitation into
14 hydrides, and then you cool down, which gives this all
15 a chance to settle in an embrittled fashion.
16 The polishing of the surface is just one
17 of three or four variables that affect this. It is a
18 very fascinating and somewhat complicated situation,
19 but the niobium alloy is different than the tin alloy.
20 So there was the question of why did this
21 Russian alloy behave so differently from the French
22 alloy. You know, we have uncovered, I think, the
23 important reasons without putting too fine a point on
24 it, and there is no -- Knowing what we do now after
25 rather intensive study in the last 18 months on this,

1 I don't think there is any reason to suspect a problem
2 with the M5 cladding.
3 CHAIRMAN POWERS: At that point, I think
4 we can turn to Steve. You're on.
5 MR. LaVIE: Well, thank you. My name is
6 Stephen LaVie. I am with the Probabilistic Safety
7 Assessment Branch. As I was waiting to get started
8 here, I was reflecting on whether it was an advantage
9 to be last on the schedule, and concluded that most of
10 the people have already said a lot of my presentation.
11 So that is an advantage -- or a disadvantage perhaps.
12 Then perhaps you guys are all kind of tired out and
13 have had all your questions already answered.
14 CHAIRMAN POWERS: No, we get even crankier
15 as the day goes on. And you are not even near last on
16 this schedule. This sucker goes on until midnight, I
17 think.
18 MR. LaVIE: Okay. I am going to discuss
19 the review of the design basis accident radiological
20 consequences evaluation.
21 Normally, the staff does not assess the
22 impact of LTAs on prior analyzed doses. This is
23 generally because the pellets are not different
24 isotopically.
25 There is no reason to assume there will be

1 an impact on the dose concentrations. But there are
2 indications on this review that MOX could increase the
3 radiological consequences and, in fact, the licensee
4 specified that in its submittal. So this forces the
5 NRC's review.
6 A review focused on the impact of the four
7 MOX LTAs on the previously analyzed radiological
8 consequences of design basis accidents. My review did
9 not look at severe accidents.
10 The Catawba units currently are
11 transitioning from the traditional TID 1484 source
12 term and the alternative source term. Presently,
13 Catawba's licensing basis source term is TID 14844,
14 with the exception of the two fuel handling accidents
15 which are based on the alternative source term.
16 As a result, the acceptance criteria then
17 was 10 CFR Part 100 for the off-site doses of
18 everything except the fuel handling accidents, GDC-19
19 for the control room doses, and then 50.67 for the
20 fuel handling accident in the first fuel drop.
21 We had several REIs. The review did focus
22 on the licensee's submittal. Our approval is based on
23 the licensee's submittal. However, the staff
24 performed independent calculations of the licensee's
25 work.

1 Our staff's confirming calculations
2 included inputs from Sandia Lab, Pacific Northwest
3 Labs, and source term and gap fractions. The
4 conclusion of our review was that we agreed with
5 reasonable assurance that the licensee's conclusion
6 that the four MOX LTAs would have minimal impact on
7 the prior analysis results was correct. All doses
8 continue to meet the acceptance criteria.
9 I don't have to say too much about this,
10 because Steve mentioned most of this. There were two
11 groups of accidents analyzed, those which were large
12 fraction and a small fraction. The small fraction we
13 didn't spend an awful lot of time on, because as Dana
14 very eloquently pointed out, it really doesn't make a
15 whole lot of difference.
16 We did check the math and the scaling
17 calculation, and we did detect an error that the
18 licensee corrected. But the first group is more of
19 interest to us, because we are dealing with a fuel
20 handling accident design basis. It would be
21 conservative to assume that the dropped assembly would
22 be the one that was an LTA.
23 The other form that falls in this category
24 is the weir gate being dropped in the spent fuel pool,
25 which is postulated to damage seven assemblies. We

1 assumed in this case that -- and the licensee assumed
2 -- that four of those assemblies would be the LTAs.
3 Obviously, you recognize the probability of this is
4 probably pretty low.
5 Now for this particular category, the
6 licensee recalculated the dose consequences of the
7 accident using updated spent fuel inventory and an
8 assumed 50 percent increase in the gap fractions.
9 Part of the second group involved the ones
10 where the MOX LTAs were a small fraction. One of the
11 points I would like to make regarding the LOCA is that
12 there have been some comments made here and in other
13 proceedings that I need to clarify, because I think
14 they were misunderstood a lot, that in the design
15 basis accident space the radiological analysis assumes
16 there is core melt.
17 As a defense in depth measure, my
18 colleagues in Reactor Systems go to great lengths to
19 show that the fuel performance and ECCS performance
20 will prevent that from happening. So the design basis
21 accident space, we got to recognize, is the disconnect
22 between the thermal hydraulic analysis which proved no
23 fuel damage and the radiological analysis that start
24 off assuming there was.
25 Since our assumption there was is rather

1 arbitrary, the impact of MOX on that arbitrary
2 decision is not all that strong. Add that to the fact
3 that it is only two percent of the assemblies
4 affected.
5 In addition -- It hasn't been mentioned
6 earlier, but in addition to the accidents they already
7 had in their licensing basis, the licensee performed
8 an analysis of the consequences of a fresh fuel drop.
9 I point out, none of these -- These accidents are
10 typically not performed. I can't think of any other
11 licensee that has this analysis in their license
12 basis.
13 This is typically because the uranium
14 assemblies have very low specific activity. For the
15 low specific activity, they are not a big dose
16 contributor. However, as the licensee pointed out and
17 as we concur, is that the specific activity of the
18 plutonium isotopes is significantly higher, and it was
19 warranted to have a look at what the dose consequences
20 would be of a dropped assembly.
21 Now the licensee's analysis methods were
22 largely based on methods used by Sandia Labs for the
23 Yucca Mountain calculations, and also those are
24 methods used by the Office of Nuclear Materials and
25 Safeguards for looking at fuel fabrication facilities.

1 Okay. When staff did its review, we were
2 focused on three major aspects of what we believed was
3 the MOX fuel use. First was the change in the fission
4 product inventories. Second was the change in the gap
5 fractions. The third one, which only applies to the
6 fuel handling accident, was the change in the fuel rod
7 pressurization.
8 The fuel rod pressurization is an impact
9 that accident, because our assumptions regarding the
10 decontamination of the iodine as it bubbles through
11 the pooled water is dependent on the rod pressure.
12 For the fission product inventory, the
13 licensee had used the scale suite from Oak Ridge,
14 particularly the SAS2H/ORIGEN-S code, to generate the
15 fuel inventory. The licensee determined the MOX LTA
16 inventory to burnup at about 17 gigawatt days per
17 metric ton uranium.
18 The reason it was done at this point is
19 that the licensee had done a sensitivity analysis and
20 found out that the iodine peaks at that point. So
21 doing the calculation at this point maximized the
22 amount of iodine.
23 The SAS2 -- I should say this slowly so
24 you can catch it. The SAS2H code is particularly well
25 suited for this application, since it calculates the

1 cross-sectional libraries that are used by ORIGEN on
2 a case by case basis and, as such, could be structured
3 to address the MOX LTA fuel isotopics and
4 configuration directly. We weren't using a generic
5 off-the-shelf library.
6 In addition, the staff obtained some data
7 files generated by Sandia Labs using ORIGEN-2.2 for
8 purposes of comparison. In order to confirm that the
9 licensee's basing its irradiation on the peak iodine
10 inventory would not overlook a significant increase in
11 another radionuclide, the staff evaluated the
12 inventory at the end of the first, second and third
13 cycles.
14 The staff used the SAS2H code for this
15 purpose and took the maximum inventory of the three
16 cycles, nuclide by nuclide, for its confirming
17 calculations.
18
19 The observed increase in the iodine 131
20 inventory in the MOX LTA as compared to an LEU
21 assembly was about nine percent, the value used by the
22 licensee in its scaling calculations.
23 Now the licensee used iodine 131 in the
24 thyroid dose for the purposes of scaling, concluding
25 that this would be the most limiting isotope, the most

1 limiting dose limit.

2 In order to confirm that, the staff looked
3 at the impact of the increased noble gases. Some of
4 the noble gases will increase over the cycles. We
5 confirmed that the licensee's reliance on iodine 131
6 in the thyroid dose was bounding in the design basis
7 space.

8 Another issue was the gap fractions. For
9 assessing the gap fractions, the NRR staff requested
10 the assistance of the research folks to perform a
11 fission gas release analysis for the MOX LTAs.
12 Research utilized the staff at Pacific Northwest
13 Laboratories to perform this assessment with the
14 FRAPCON-3.2 code.

15 Now the FRAPCON version 3.2 had been
16 modified for use with MOX fuel as associated with its
17 use in the review of the COPERNIC topical report.
18 Changes to this code included adding thermal
19 conductivity model for MOX fuel.

20 Adjustment was made to the fission gas
21 release model diffusion constants to reflect the
22 differences noted between predicted versus measured
23 fission gas in MOX fuel assemblies. MOX fuel
24 plutonium isotopics were addressed, and they made a
25 change to the xenon-krypton ratio that used in the

1 code.

2 Now the primary model in the FRAPCON code

3 is a Massih model which can only provide predictions

4 of the stable noble gas nuclides. We, of course, need

5 to know the radiological ones.

6 To obtain the yields for the

7 radionuclides, PNNL used the ANS-5.4 model, which is

8 part of FRAPCON, but adjusted the inputs to obtain the

9 same stable noble gas output from the ANS-5.4 model

10 that they had obtained from the M-a-s-s-i-h model.

11 This is because the ANS-5.4 model is known

12 to overpredict fission product release fractions. So

13 in essence, they normalized the M-a-s-s-i-h model.

14 With that change done, the ANS-5.4 model predicts the

15 radionuclides.

16 The FRAPCON runs also showed that the end-

17 of-life rod pressurization was less than 1200 psia.

18 As such, the Safety Guide 25 assumptions regarding

19 the spent fuel pool decontamination credit remain

20 valid.

21 This table here -- next slide, please.

22 This table here shows the gap fractions breakdown. I

23 need to point out very carefully here that we are

24 talking about non-LOCA gap fractions.

25 The numbers in Regulatory Guide 1.183

1 which address LEU are shown in the first column. The
2 licensee assumed a 50 percent increase, and those
3 numbers are shown in the second column. The staff's
4 evaluation, based on the work done by PNNL, are shown
5 in the third column.
6 You can notice that the numbers in the
7 third column are bounded by the licensee's
8 assumptions. There's a couple of ones that need to be
9 addressed -- a couple of items that I didn't talk
10 about here.
11 The reason there is a range in the staff
12 ones is that PNNL had discovered a difference between
13 the power history submitted by Duke in terms of burnup
14 versus time and the F delta H values in the same
15 table. So PNNL had done it using both sets of data.
16 PNNL also tacked on a five percent margin to address
17 uncertainties in the power history. So that's why you
18 see a range for the staff's evaluation.
19 With regard to the alkali metals, the
20 licensee is marked here as not applicable. The LTA
21 gap fractions were used by the licensee only in the
22 fuel handling accident.
23 The design basis fuel handling accident
24 assumptions provide that particulate material will be
25 retained by the pool. Hence, cesium was not an issue.

1 Maybe it will be an issue in the future if they pursue
2 with the batch.
3 The reason it isn't addressed as a LOCA,
4 the locked rotor accident or the rod ejection
5 accident, is cesium is not part of the TID 1484 source
6 term, which is the licensing basis for Catawba
7 primarily.
8 The staff, of course, expects to get some
9 input out of the post irradiation examinations as to
10 find out where their numbers fall with measured data.
11 That is my comments.
12 CHAIRMAN POWERS: Any questions to pose to
13 Steve? Thank you.
14 Steve, your post irradiation examinations
15 of the gap inventories -- how accurate do you need
16 those numbers?
17 MR. LaVIE: For the LTAs not very accurate
18 at all, as we pointed out, with only two percent of
19 the assemblies.
20 I do want to make a point about why that
21 is significant. In doing the analysis, when they the
22 scaling analysis for the LOCA, Duke applied the 50
23 percent increase to all the release fractions. Of
24 course, this is based on TID 1484. There's only one
25 release space.

1 The iodine assumption in the TID is 50
2 percent. So in reality, they did the calculation
3 assuming that 75 percent of the iodine in those four
4 LTAs was released. The dose went form 89.3 rem to 91
5 rem. Even if they had released 100 percent of the
6 iodine in the LTAs, they still would have been well
7 within acceptance criteria.
8 So how accurate we need those numbers is
9 going to depend on -- For the it doesn't depend at
10 all. In the future it may become important if they
11 pursue a batch amendment.
12 They had plenty of margin in the fuel
13 handling accident as well. The dose cited was down
14 like at 1.2 rems or something like this nature. It
15 was out of an allowable 25.
16 CHAIRMAN POWERS: Any other questions?
17 DR. TRIAFOROS: Yes, I have another
18 question. This is on issues that we discussed, a
19 little area, and it has to do with the fact that the
20 subjects that are addressed in the safety evaluations
21 are -- The evaluation is good up to a burnup of 60
22 gigawatt days per metric ton of heavy metal.
23 Now the safety evaluation -- the subjects
24 are addressed in the safety evaluations. They refer
25 to their COPERNIC code which, based on our review of

1 the safety evaluation of the COPERNIC code, it is
2 approved to 50 gigawatt days per metric ton heavy
3 metal, and it is an apparent inconsistency there. I
4 would appreciate if you can elaborate.
5 MS. SHOOP: Certainly. that is an issue
6 that the intervenors have also raised. Basically,
7 going back to what I started out with originally, the
8 purpose of an LTA is to gather data.
9 Now how do you gather data? You can only
10 gather data by burning it. How do you approve a code?
11 Well, you can only approve a code if you have data.
12 So you've got the chicken and the egg conundrum. I
13 mean, you need data to support a code approval, but
14 how do you get data if the code is not approved there?
15 So what we have done with LTAs and what
16 has been reactor systems' common practice is we
17 understand that the purpose of LTAs is to collect data
18 and, therefore, we will extend the use of a code to an
19 area where we believe that it is still good.
20 Framatome actually did provide some
21 information or data between the 50 to the 64 gigawatt
22 day range. However, that data was not statistically
23 significant, and that is why we did not approve it up
24 to 60.
25 CHAIRMAN POWERS: Any other questions to

1 pose? Well, good. What I wanted to do is just take a
2 few minutes here to discuss presentations in front of
3 the full Committee. I'm going to handle this one
4 right now with Bob, and then we will go on to the rest
5 of our agenda.
6 Bob, we have scheduled a two-hour block of
7 time at the May meeting to discuss this, and the
8 question before us is twofold.
9 One, do we need to have the applicant
10 appear and redo his -- any portion of his
11 presentation? Second, what fraction of the afternoon
12 that you have presented here do we want to present in
13 front of the full Committee?
14 I would invite the members to voice their
15 opinions on that particular subject, those questions.
16 DR. KRESS: Well, I think if it is not too
17 much of an imposition, we would like to have the
18 applicant come back, partly because the Committee gets
19 an impression from hearing the applicant.
20 My guess on that would be I thought the --
21 Well, in the first place, the extra data from
22 Framatome was good, but I don't think -- I think we
23 can just present that to them in slides or something.
24 I felt Nesbit's safety and environmental
25 evaluation would be important to get in.

1 CHAIRMAN POWERS: My suggestion was that
2 if Mr. Nesbit could factor into his presentation some
3 of the slides on the fuel properties and
4 microstructures --
5 DR. KRESS: That might be the way.
6 CHAIRMAN POWERS: Just to augment some of
7 the points that he ordinarily makes, that that might
8 be a particularly succinct way to make his points in
9 front of the full Committee.
10 DR. KRESS: I also thought that -- You
11 know, the Committee is going to be interested in the
12 nuclear stuff, nuclear analysis. So if we get some
13 abbreviated part of that -- I don't think the full
14 thing.
15 CHAIRMAN POWERS: Maybe again just augment
16 the points made.
17 DR. KRESS: Yes. And personally, I also
18 think it was very useful to hear BREDL's concerns.
19 CHAIRMAN POWERS: Oh, yes.
20 DR. KRESS: And so if we can impose on
21 them to more or less repeat those.
22 CHAIRMAN POWERS: Okay. I'll ask Mr.
23 Lyman if he can bring those forward to us as well. I
24 don't know. I haven't spoken to him about that, but
25 we will. Mario?

1 DR. BONACA: Well, I agree with what Tom
2 is suggesting. One thing that it is important. It
3 would be valuable to have just a brief description on
4 the slide of the isotopic composition of this MOX fuel
5 versus the one that we saw in Europe, because
6 otherwise there is an implicit assumption that they
7 are similar, period.
8 Well, they are not that similar. The
9 reason why it is important is that -- For four lead
10 test assemblies I don't think it is important, but
11 really when you talk about the future, it is
12 important, and so I think it is beneficial to present
13 it that way.
14 The other thing which is interesting is
15 that, in licensing four lead test assemblies, you do
16 have a fundamentally different philosophy in the
17 justification that you will have for the full court,
18 because what you are doing is strategically
19 positioning your LTAs in certain locations, and for
20 most advanced generalizing that is the way you say,
21 well, you know, it's not -- the leading assemblies is
22 not limiting.
23 It would be different when you go in and
24 you insert 40 percent of assemblies or whatever you
25 are going to insert. So even that would be an

1 important point to make, I think. Since we have such
2 little time there, these are important issues that you
3 want to communicate.
4 I thought, within that context, the
5 presentation we had on the French experience was very
6 valuable, because it clearly tells me there is a lot
7 of information out there that, taken in proper
8 consideration of what differences it may be, says this
9 is not a new venture. I mean, this is really
10 something for which there is a solid basis.
11 So I also thought the radiological
12 analysis was important, because it conveys some of
13 those messages there.
14 CHAIRMAN POWERS: Professor Ransom, any
15 comments?
16 DR. RANSOM: I think the same thing. I
17 would like to see the French experience emphasized.
18 I think that adds a lot of credibility to what is
19 being done, or certainly minimizes the risk of the LTA
20 question itself.
21 As far as I am concerned, it seems like
22 very convincing argument, and I would guess you
23 probably want to summarize what --
24 CHAIRMAN POWERS: We are not going to
25 allow sufficient time for the full presentation, but

1 if some of the salient points can be brought forward,
2 it would be useful. Graham?
3 DR. LEITCH: I have nothing to add. Mario
4 made the comment that I was going to make.
5 CHAIRMAN POWERS: Okay. What I would
6 propose then is that we will kind of divide the time
7 up equally between the staff and the applicant, and
8 then ask Mr. Lyman what time he thinks he would need,
9 if he can in fact be there, and do that.
10 So that brings us to the question of how
11 to -- what to do with your time. Let me say at the
12 beginning, I thought the staff's presentations were
13 uniformly excellent.
14 MR. MARTIN: Thank you.
15 CHAIRMAN POWERS: And so it is very
16 difficult for me to come in here and tell you what
17 part to cut out. So I may just say figure out how to
18 present all that material, but do it in a lot shorter
19 time. This is not an unusual command from the ACRS,
20 but yes, I think you are going to struggle on doing
21 that, because I thought the presentations across the
22 board were just excellent.
23 MR. MARTIN: Thank you, and I appreciate
24 being able to go ahead with the May meeting. There
25 are some considerable scheduler concerns related to

1 hearing activities for any June time frame which make
2 being able to go ahead with the May meeting very
3 valuable.
4 CHAIRMAN POWERS: I think, regardless of
5 the outcome of your meeting with the applicant that
6 simply getting the rest of the ACRS on board and up to
7 speed will just make it more efficient if we have to
8 come back for some reason, and make it a little more
9 efficient.
10 MR. MARTIN: Right.
11 CHAIRMAN POWERS: Without having the
12 outcome from your meeting, I can't say for sure, but
13 anything that is not heroic would not move me to have
14 another subcommittee meeting.
15 MR. MARTIN: Okay.
16 CHAIRMAN POWERS: Let me turn -- I see Dr.
17 Lyman is in the audience. You have a command
18 performance here, sir. Would you be able to help us?
19 DR. LYMAN: Yes, indeed.
20 CHAIRMAN POWERS: Now you've got me.
21 MR. CARUSO: So the first week in May, the
22 Thursday and Friday, the 6th and 7th.
23 DR. LYMAN: Sixth and seventh?
24 CHAIRMAN POWERS: Well, you guys will
25 interact. I think sensibly, we are asking for your --

1 rehash -- not rehash but a repetition of your
2 presentation in front of the full Committee.
3 DR. BONACA: And it would be interesting
4 to know, again on the point I was making before of
5 four lead assemblies versus 40 percent of the core --
6 It would be interesting if some of the issues that
7 were raised and you addressed, you know, would be of
8 more significance in consideration in the future,
9 because you are doing something about that.
10 For example, location, you are telling me
11 that you are still -- It would be interesting for the
12 members to understand that in context. Again, it may
13 not be an issue at all with four lead assemblies.
14 CHAIRMAN POWERS: I don't know that we can
15 ask them to do everything. You are going to have to
16 be more liberal with your agenda.
17 Okay, I think we've got a start on that.
18 Mr. Caruso is here to help and facilitate these
19 presentations, to the extent that they can be done.
20 At this point on the agenda, I have the
21 item for additional public comment. Do we have any
22 additional public comments based on what has been
23 heard or otherwise? Be our guest.
24 Thank you all very much. I really did
25 think your presentations were excellent. We will turn

1 to Dr. Lyman here.

2 DR. LYMAN: I would defer to the staff if

3 they have anything.

4 I appreciate the opportunity to clarify.

5 During the day's discussion there was some question of

6 what the intervenors are really seeking in this case.

7 So I just wanted to clarify that BREDL isn't seeking

8 absolute certainty. That is not the goal, and we

9 understand that is unrealistic, and we also don't want

10 to curtail scientific investigation by making

11 conditions impossible to do any research on

12 irradiation of LTAs.

13 In this case, we aren't talking about an

14 incremental change in the type of fuel, but we are

15 talking about a significantly new type of fuel in the

16 U.S. experience, and to that extent, I think there

17 have to be greater demands and reviews of the MOX LTA

18 application than on the typical LTAs situations.

19 Now to some extent, that's occurred, but

20 given the large body of data accumulated over decades

21 with conventional LEU fuels, including under accident

22 conditions, and comparing that to the relative paucity

23 of data for MOX fuel under similar accident conditions

24 and the fact that the few data points that have

25 accumulated from MOX seem to suggest that there may be

1 some issues that need greater observation, then we
2 would say that would indicate a more thorough
3 licensing basis before experimenting with these LTAs
4 in U.S. reactors.
5 So that is the context, not that we demand
6 absolute certainty, but just a greater -- There should
7 be greater curiosity, I think, on the part of the
8 NRC's staff review than there is, investigating some
9 of these issues that have emerged.
10 In light of Dr. Bonaca's observation, to
11 the extent that this application is approved largely
12 on the basis of the relatively small number of
13 assemblies that are affected and not on an
14 understanding of the underlying physics and other
15 properties of these assemblies, they will only come
16 back to haunt everyone when the batch application
17 comes in.
18 So it probably would make sense to start
19 trying to nail them down at this point to avoid delays
20 later.
21 The next point regarding source terms, I
22 would just like to point out that, obviously, the
23 deterministic -- the old deterministic TID source term
24 doesn't include consideration of release of any of the
25 refractory radionuclides, and considering that the

1 largest inventory differences when you are talking
2 about MOX fuel lie in plutonium and the higher
3 actinides, not considering that is an oversight which
4 I think at least needs to be addressed even though it
5 is only going to affect a small number of fuel
6 assemblies in this case, especially given if there are
7 any indications from VERCORS tests that the potential
8 release fractions of low volatiles are higher than
9 what have been anticipated.
10 So none of that was considered in the
11 application under review. Whole body doses were
12 largely not considered, even though, as I mentioned
13 before, two isotopes which the staff didn't mention
14 which have higher -- substantially higher inventories
15 in MOX fuel, including the ruthenium isotopes which
16 are well over 50 percent greater in MOX, and the
17 tellurium isotopes which would contribute to whole
18 body doses were not considered, and looking only at
19 the iodine source term and doses.
20 Finally, my last remark on post
21 irradiation examination: If the staff is indeed
22 requiring -- and I'm not sure this is a commitment,
23 because I haven't double checked, but if they are
24 requiring that the hot cell PIE be concluded before
25 the batch application can be approved, I would suggest

1 looking at that in the context of the current
2 schedule, which doesn't seem to allow much time for
3 that analysis to be completed before an approval would
4 be required, since the fuel wouldn't be discharged
5 after two cycles until spring 2008, and the current
6 schedule is still that batch loading would start
7 sometime in 2099. So factoring in the time for
8 cooling, transport and analysis, it seems like that is
9 cutting it awfully close.
10 That's all I have to say. Thank you.
11 CHAIRMAN POWERS: Thank you. Does the
12 staff have any comments they would care to make?
13 MS. SHOOP: Thank you, Dana. Actually, I
14 heard Dr. Bonaca, and I believe that Graham also
15 believes the same, that for the full Committee meeting
16 they would like us to discuss the difference between
17 LTA and batch.
18 Batch application at this point is
19 completely speculative. There is no application in
20 front of us for batch loading of MOX fuel and,
21 therefore, and because it is not part of this
22 application, I think that that would be the wrong
23 thing to put our time toward.
24 We have a very limited amount of time and,
25 therefore, we should address what this application is,

1 and this application is not for batch loading.

2 DR. BONACA: No, I want to make sure, I

3 didn't say you have to address batch. I simply point

4 out that the licensing of batch will be different, and

5 therefore, you would be looking at different things.

6 I'm just putting in context the fact that the LTA

7 doesn't resolve all the issues to do with the

8 differences. That would come later.

9 It will be a different kind of challenge,

10 however, than purely for four LTAs.

11 MS. SHOOP: Okay. Thank you for

12 clarifying that.

13 CHAIRMAN POWERS: I agree with you. We

14 simply don't have time to delve into any kind of

15 detail on this, but a cautionary note on that never

16 hurts, and Mr. Nesbit, you, too, might want to

17 introduce a cautionary note that the batch application

18 clearly involves something different.

19 DR. KRESS: I wouldn't speculate on any of

20 the outcomes.

21 CHAIRMAN POWERS: Dr. Meyer, you would

22 like -- you have a word that you would like to pass

23 on?

24 DR. MEYER: Yes. There is one thing that

25 was said earlier in the meeting that has been on my

1 mind, and I would like to come back to it.

2 It was something that Mr. Nesbit said

3 about the reactivity accidents, the rod ejection

4 accident somehow being worse for mixed oxide fuel than

5 for UO_2 fuel.

6 What I wanted to point out about all of

7 this is that, if you look at what is significant from

8 a risk point of view, really, the only two events that

9 you have talked about here that might come on the

10 radar screen are the loss of coolant accident and the

11 rod ejection accident.

12 The loss of coolant accident, the effect

13 of MOX -- Well, first off, let me say that there

14 clearly are neutron physics effects of MOX, and these

15 can be and are being handled. But when you talk about

16 the fuel part of that, for the loss of coolant

17 accident any connection, any difference between MOX

18 and LEU at this time is purely speculative, and I

19 don't think there is any evidence that there is a

20 difference, although we are, of course, interested in

21 looking.

22 For the rod ejection accident, we know

23 about these plutonium agglomerates, and they can have

24 an effect on the fuel behavior during an accident.

25 But as far as we can tell from quite a number of tests

1 on MOX as well as on UO_2 fuel in pulse reactors, this
2 effect is going to show up in the dispersal
3 characteristics of the fuel rod after you have
4 breached the cladding and you now have these little
5 islands that are able to kind of pop open fuel rather
6 than just a rem of extremely high burnup material.
7 So this will be different. But the
8 criterion that is being used, both by the applicant in
9 this case and by Research in its recent study, is a
10 cladding failure threshold criterion.
11 We are using -- The numbers that we talked
12 about today are numbers that are so low that you can't
13 even crack the cladding open, and you can't get
14 dispersal.
15 In our analysis of this Rep NA-7 test,
16 which was the MOX test at Cabri which had a rather
17 energetic dispersal of fuel material, when we analyzed
18 that test in terms of its cladding failure threshold,
19 it is no different than any of the LEU tests.
20 So if for this accident you are using the
21 more conservative limit of the cladding failure
22 threshold as your absolute limit, then I would say the
23 evidence is that there is no difference in the fuel
24 behavior in that case.
25 So just in summary, for these two risk

1 significant events at this point I think the effects
2 of MOX fuel -- you can already see that they are going
3 to be marginal at best.
4 CHAIRMAN POWERS: I have to admit that the
5 conclusion I walked away from Mr. Nesbit's
6 presentation was identical to this.
7 DR. MEYER: Okay.
8 CHAIRMAN POWERS: I mean, he can speak for
9 himself here, but my conclusion was that that's what
10 you said, is that the clad failure was about the same
11 and that dispersal characteristics were different.
12 DR. MEYER: I must have missed that. I
13 was having a hard time hearing.
14 CHAIRMAN POWERS: It could be, but there
15 does seem to be consensus on that point.
16 Do members have any other comments they
17 would care to make? I think we have a plan of attack
18 on this. I will be chatting with you about draft
19 summaries on some of the concepts that were put
20 forward at this meeting and get your concurrence on
21 that, but we will go to the full Committee meeting as
22 planned.
23 I thank all the speakers. I complimented
24 the staff on their presentations. Mr. Nesbit, I want
25 to also congratulate you and your folks for excellent

1 presentations to us as well. I appreciated Mr.
2 Blanpain's presentation especially. We always like to
3 see microstructures on fuels and properties and data.
4 It always makes us feel like we really are scientists.
5 With that, I think I will adjourn the
6 subcommittee meeting.
7 (Whereupon, the foregoing matter went off
8 the record at 5:09 p.m.)
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CERTIFICATE

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

Name of Proceeding: Advisory Committee on Reactor Safeguards Subcommittee on Reactor Fuels Meeting

Docket Number: n/a

Location: Rockville, MD

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

John Mongoven
Official Reporter
Neal R. Gross & Co., Inc.

MOX Fuel Lead Assembly Program

Advisory Committee on Reactor Safeguards – Fuels Subcommittee
NRC Offices - White Flint, MD

Steve Nesbit
Duke Power
April 21, 2004

Duke Power. A Duke Energy Company

MOX MIXED OXIDE FUEL PROJECT

Plutonium Disposition Program

- 1994 National Academy of Sciences Report – "clear and present danger"
- September 2000 – U.S.-Russian agreement that each country will dispose of 34 tonnes of its surplus weapons grade plutonium
- Approach – fabrication into mixed oxide (MOX) fuel and use in commercial nuclear reactors
- The lead assembly program is an essential element of the plutonium disposition program
  - Required to qualify MOX fuel for use in United States reactors

Lead Assembly Program – Activities and Schedule

- Spring 2004 – Complete aqueous polishing of plutonium oxide (PuO_2) powder at Los Alamos National Laboratory
- Summer-fall 2004 – Transport PuO_2 powder to Europe
- Fall 2004 – winter 2005 – Fabricate MOX fuel pellets and rods at Cadarache and bundle assemblies at Melox
- Spring 2005 – Transport MOX fuel lead assemblies to Catawba

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MOX MIXED OXIDE FUEL PROJECT

Reactor Use of Lead Assemblies

- Catawba Nuclear Station
  - York County, South Carolina
  - 3411 MW_{th} pressurized water reactors operated by Duke Power
    - Westinghouse four loop design
    - 193 fuel assemblies in each core
    - Ice condenser containments
- Irradiation Plan
  - Load four MOX fuel lead assembies in Catawba Unit 1 (spring 2005)
  - Use all four assemblies for two cycles
    - Prototypical but not limiting power levels
    - Peak rod burnup of 48 GWD/t in two cycles
  - Use one or more assemblies for a third cycle
    - Peak rod burnup less than 60,000 MWD/t

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MOX MIXED OXIDE FUEL PROJECT

Basis for Safety Case

- Similarity between uranium and MOX fuel
- Extensive European experience base with MOX fuel
  - Manufacturing - advanced micronized master blend (MIMAS) process
  - Use - decades of experience in dozens of reactors
- Similar to prior U.S. MOX fuel lead assembly programs
- Proven fuel assembly design
- Analyses and evaluations of MOX fuel impacts at Catawba

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MOX MIXED OXIDE FUEL PROJECT

Required Regulatory Approvals

- Duke topical reports (thermal-hydraulic, nuclear analysis)
- AREVA topical reports (COPERNIC, fuel assembly design, MOX fuel design)
- Duke license amendment request and exemption requests
- Duke security plan changes and exemption requests
- DOE export license application
- Duke Cogema Stone & Webster transportation package certifications

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MOX MIXED OXIDE FUEL PROJECT

Summary

- The United States MOX fuel lead assembly program is a key element of the international initiative to reduce the stockpiles of weapons grade plutonium in the United States and Russia
- Several NRC approvals are needed to support the lead assembly program

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A Duke Energy Company

MOX
MIXED OXIDE FUEL PROJECT

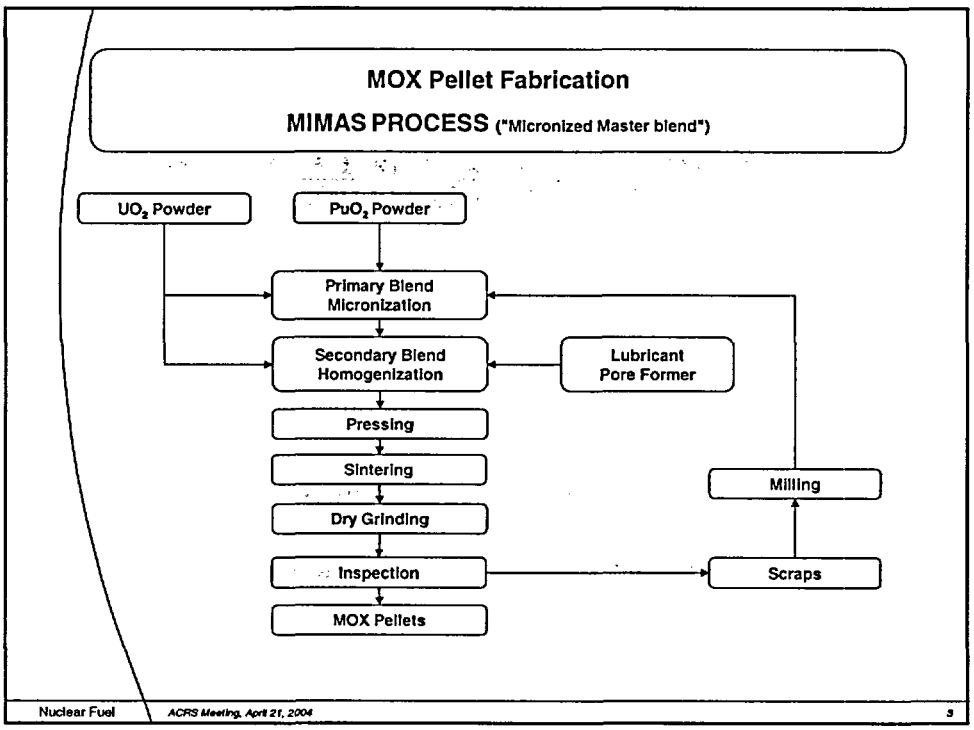
MOX FUEL: FABRICATION, EXPERIENCE AND PERFORMANCE

ACRS Fuels Subcommittee Meeting, April 21, 2004

Patrick Blanpain – Framatome ANP

STATUS OF MOX FUEL USE IN EUROPE

- Since the first commercial reloads in 1972 in Germany and in 1987 in France, Pu recycling in the form of MOX fuel, has reached an industrial maturity.
- A production capacity (used by Framatome ANP) of 140 Thm/year (MIMAS process) in the French (Melox) and in the Belgian (Belgonucleaire) plants.
- More than 2400 FAs delivered by Framatome ANP/France to 20 French, 2 Belgian and 4 German PWRs (end 2003).
- More than 1300 FAs delivered by Framatome ANP/Germany to 11 German and 3 Swiss PWRs and BWRs.


MOX Pellet Fabrication
MIMAS PROCESS ("Micronized Master blend")
UO_2 Powder
PuO_2 Powder
Primary Blend Micronization
Secondary Blend Homogenization
Lubricant Pore Former
Pressing
Sintering
Dry Grinding
Inspection
MOX Pellets
Milling
Scraps
Nuclear Fuel
ACRS Meeting, April 21, 2004
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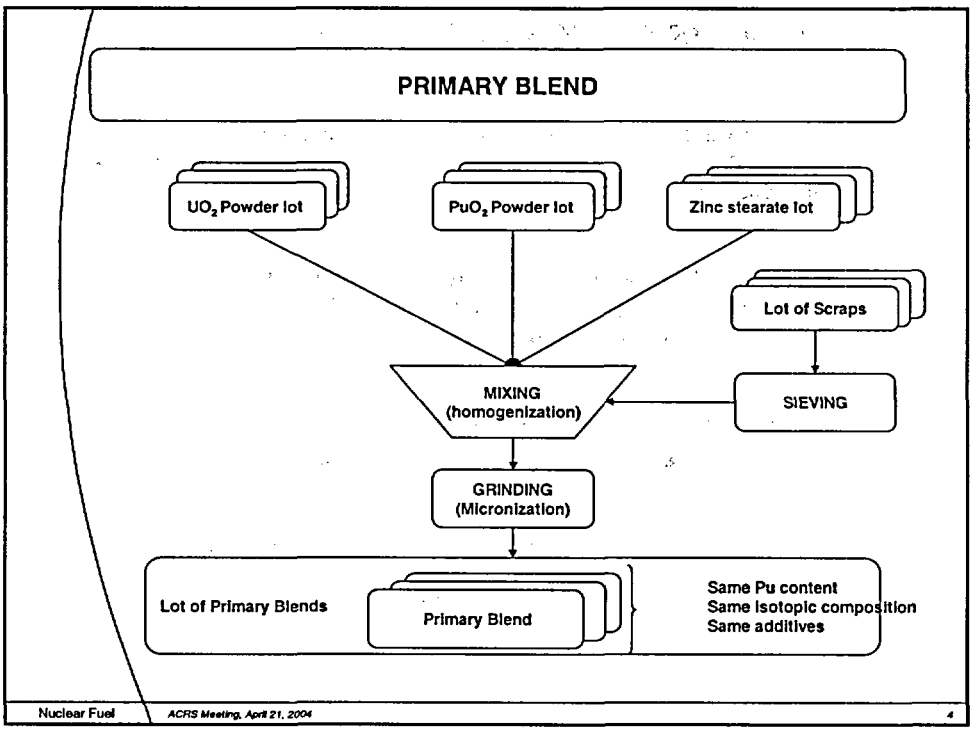
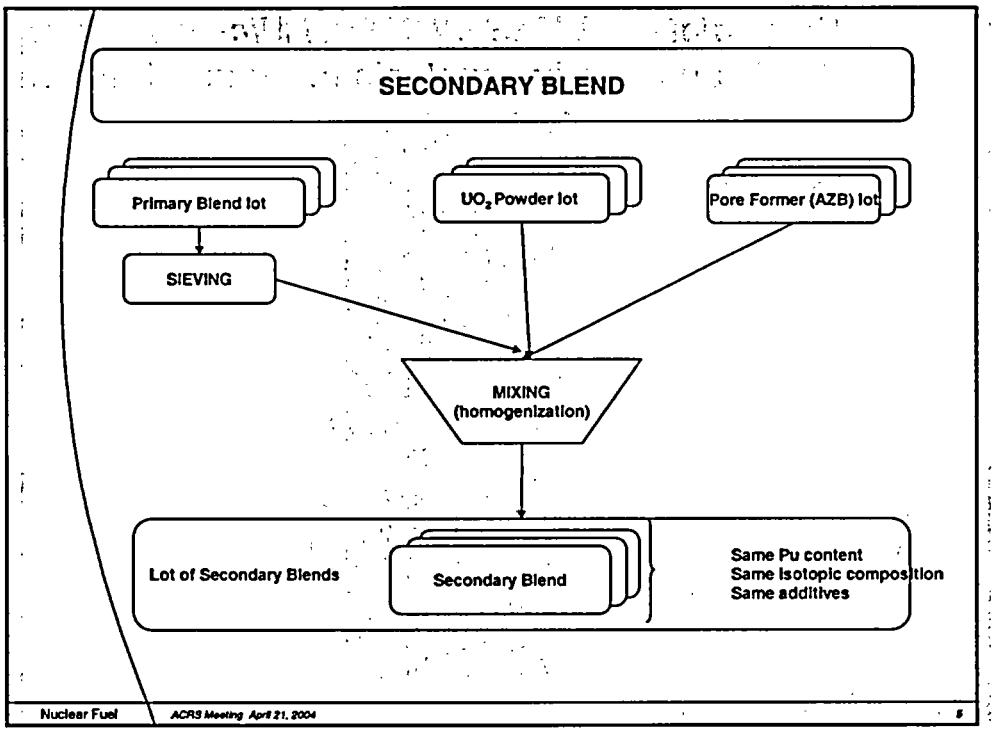
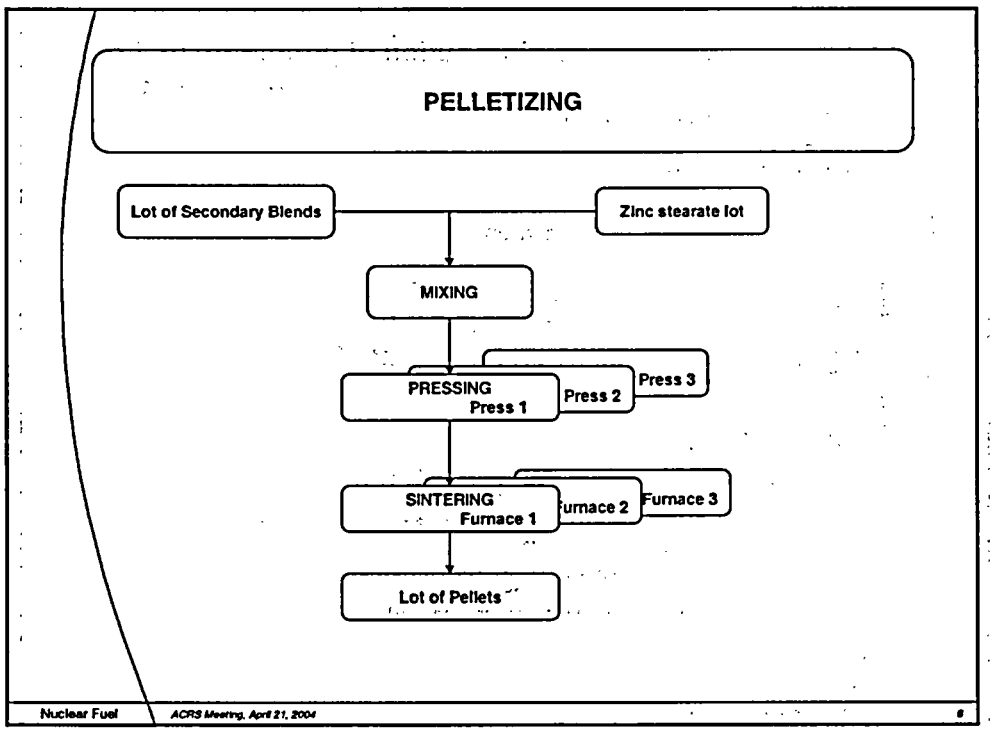

PRIMARY BLEND
UO_2 Powder lot
PuO_2 Powder lot
Zinc stearate lot
Lot of Scraps
MIXING (homogenization)
SIEVING
GRINDING (Micronization)
Lot of Primary Blends
Primary Blend
Same Pu content
Same isotopic composition
Same additives
Nuclear Fuel
ACRS Meeting, April 21, 2004
4


SECONDARY BLEND
Primary Blend lot
UO_2 Powder lot
Pore Former (AZB) lot
SIEVING
MIXING
(homogenization)
Lot of Secondary Blends
Secondary Blend
Same Pu content
Same isotopic composition
Same additives
Nuclear Fuel
ACRS Meeting April 21, 2004
5


PELLETIZING
Lot of Secondary Blends
Zinc stearate lot
MIXING
PRESSING
Press 1
Press 2
Press 3
SINTERING
Furnace 1
Furnace 2
Furnace 3
Lot of Pellets
Nuclear Fuel
ACRS Meeting, April 21, 2004
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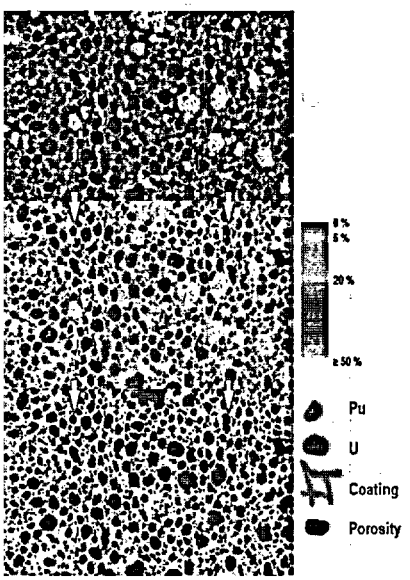
Unirradiated MIMAS MOX Fuel Microstructure
EPMA: quantitative analysis of Pu distribution

As-measured image

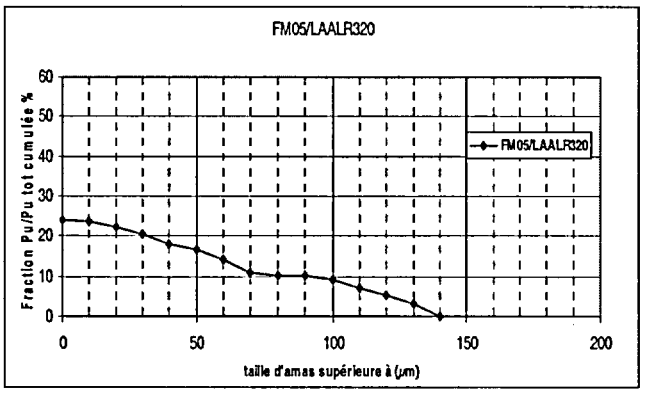
After image analysis



Cumulative distribution of plutonium in the agglomerates

- *24 ± 6 % in PuO_2 agglomerates*
- *72 ± 6 % in coating phase*
- *4 ± 1 % in UO_2 phase*

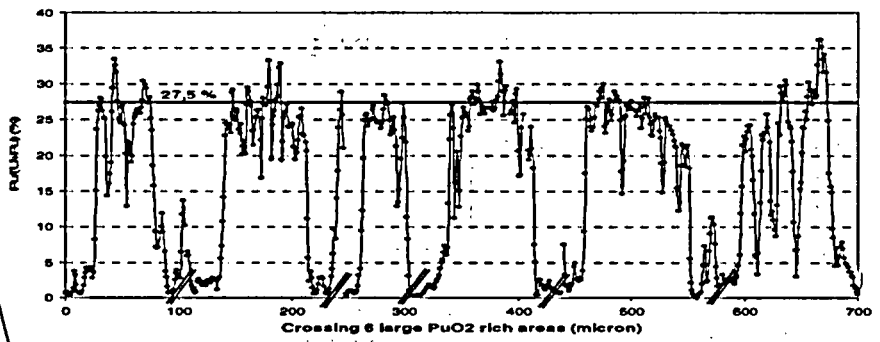
» cumulative Pu/Pu tot fraction



» agglomerate size larger than (µm)

Plutonium micro-distribution: EPMA analysis

▶ Large agglomerates in unirradiated fuel:



» *The Pu content in agglomerates = Pu content of the master blend*

STATUS OF MOX FUEL USE IN EUROPE

▶ LWRs up to 1300 MWe and different FA mechanical designs.

▶ Different neutronic design and fuel management:

- Pu total content up to ~7.5 % average FA;
- equ. U^{235} enrichment up to 4.3 %;
- 1/3, 1/4 core loading schemes;
- recycle rate: usually 30% MOX FA in core (50% licensed in Germany, 38 % used);
- UO_2 matrix: $U_{depleted}$ or U_{nat} .

▶ Discharge FA burnups of 45-50 GWd/tHM, and up to 60 GWd/tHM for individual FAs.

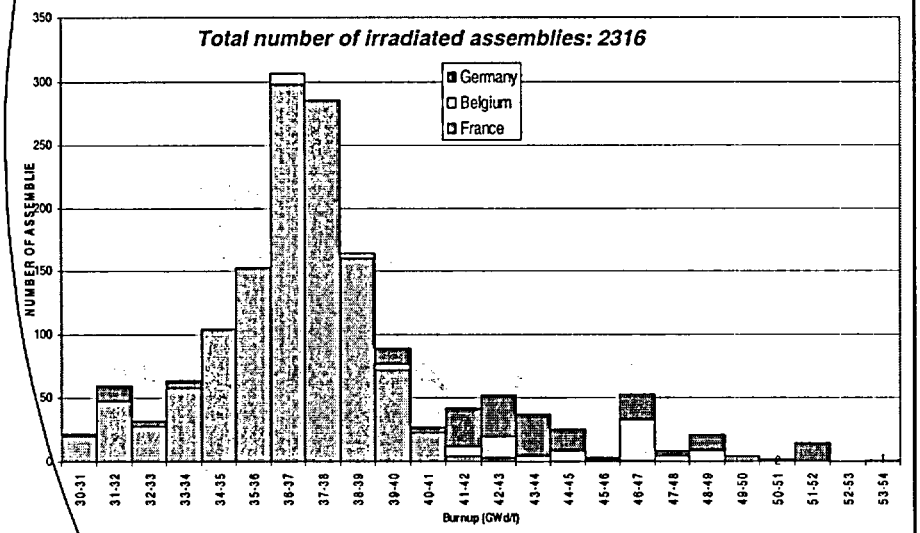
▶ MOX fuel can operate in load follow mode.

▶ Same failure rate as LEU fuel: no rod ever failed for MOX-specific reasons.

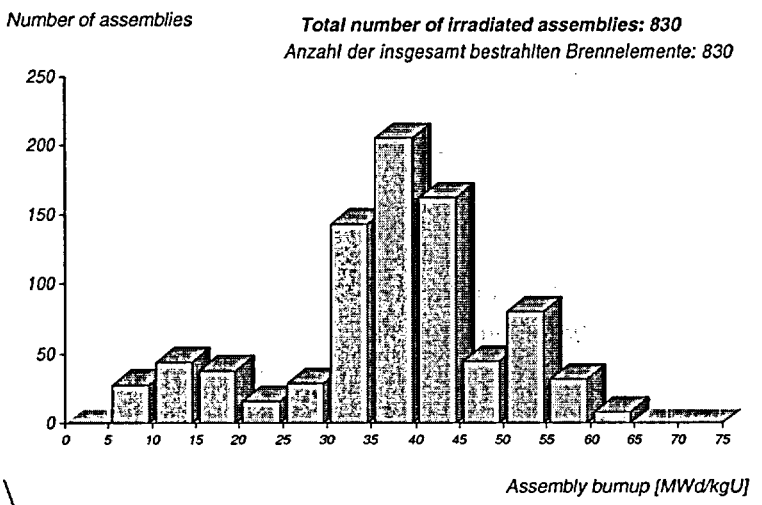
Framatome ANP PWR MOX ASSEMBLIES

FRAMATOME ANP

FRAMATOME/FRANCE- MOX EXPERIENCE AS OF June 30, 2003



Framatome ANP PWR MOX ASSEMBLIES (ex-Siemens, Status 12/2003)



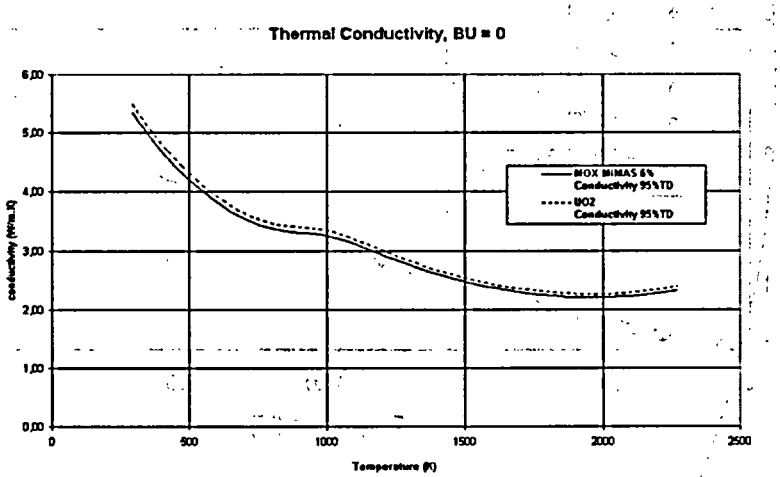
MOX FUEL DESIGN AND PERFORMANCE

▶ The mechanical design of the FA structure identical for LEU and MOX FAs.

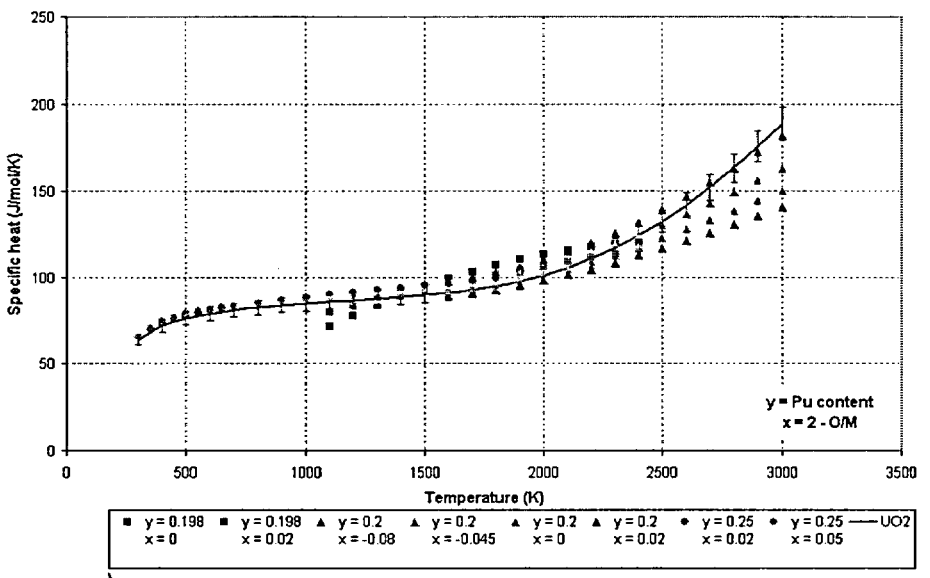
▶ Reliable prediction of the thermo-mechanical behaviour of the fuel rods:

- adequate description of the MOX-specific properties;
- design models and codes continuously verified by comparison with measurements;
- same level of accuracy as for uranium fuel.

MOX Fuel - Thermal Properties

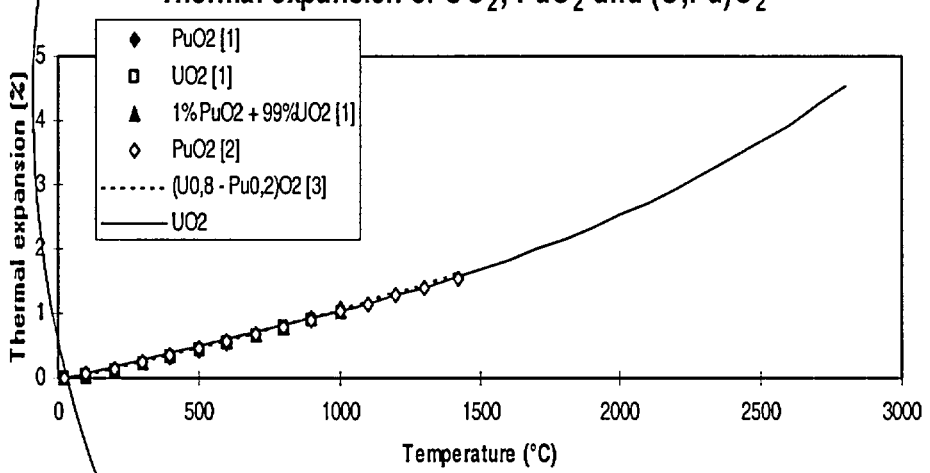


MOX Fuel - Thermal Properties - Specific heat



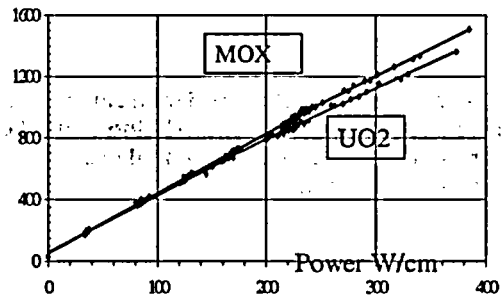
MOX Fuel - Thermal Properties

Thermal expansion of UO_2, PuO_2 and $(U,Pu)O_2$



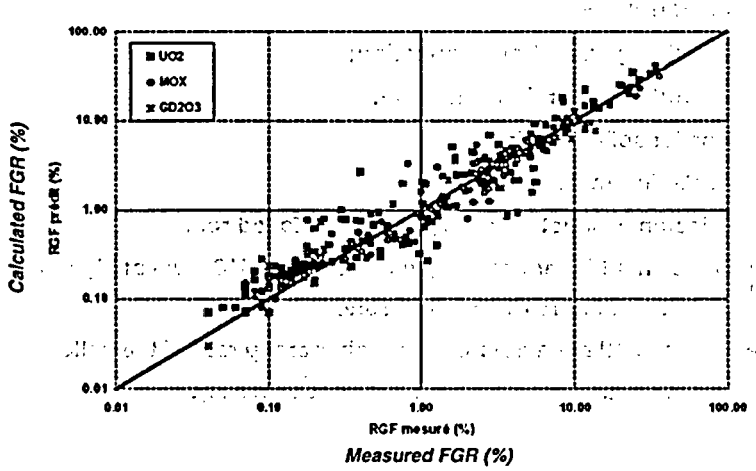
In-pile measurement of fuel centre-line T°
BU = 0 - 5 GWd/tM

Central Temperature ^{0}C



Fission gas release prediction (COPERNIC)

» *UO2, (U,Gd)O2 and MOX Fuels*



MOX FUEL DESIGN AND PERFORMANCE

▶ Experience feed-back (surveillance and analytical programmes):

- - about 100 commercial fuel rods (French & German regions) examined in hot cells (burnup up to 63 GWd/tHM, - 5 cycles);
- - power ramp testing and instrumented analytical irradiations have been or are being carried out up to high burnups (national & international programs): PCI, FGR, T°, in-pile densification...

MOX FUEL DESIGN AND PERFORMANCE

▶ Same behaviour of MOX and UO_2 fuels concerning:

- fuel rod growth;
- cladding diametral deformation;
- cladding waterside corrosion;
- pellet solid swelling;
- ZrO_2 internal layer;
- fission product & activity release of failed rod.

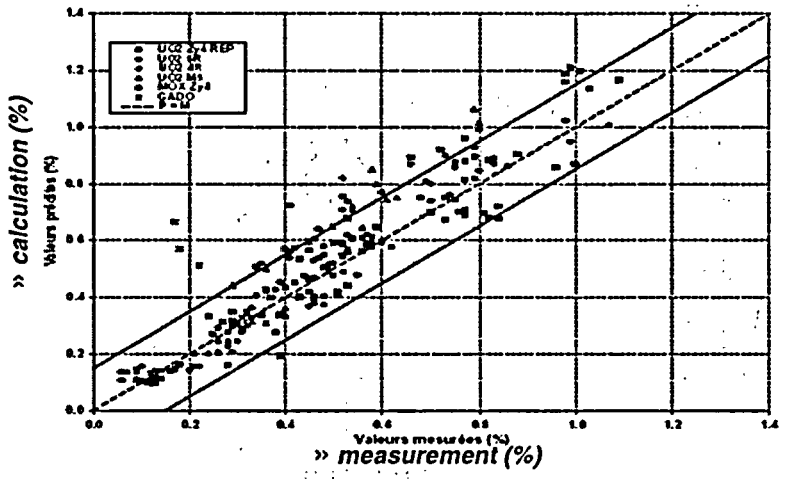
▶ Somewhat higher fission gas release than UO_2 fuel at high burnup.

- Higher fuel rod internal pressure.

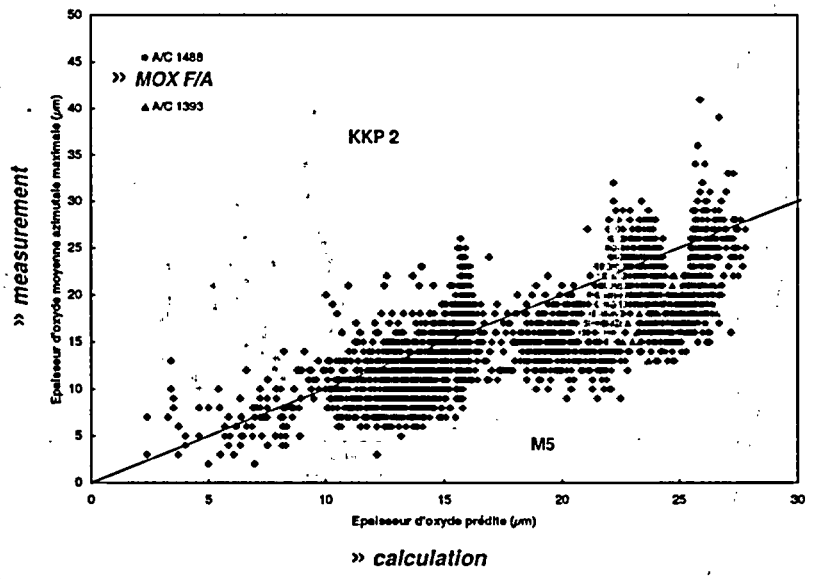
▶ Better PCMI behaviour due to higher creep rate of the pellet.

- MOX fuel not limiting vs. plant manoeuvrability.

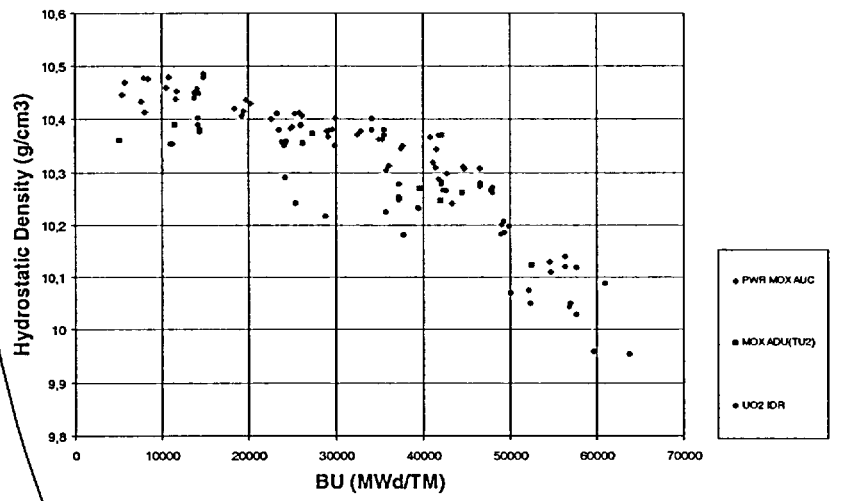
Fuel Rod Growth



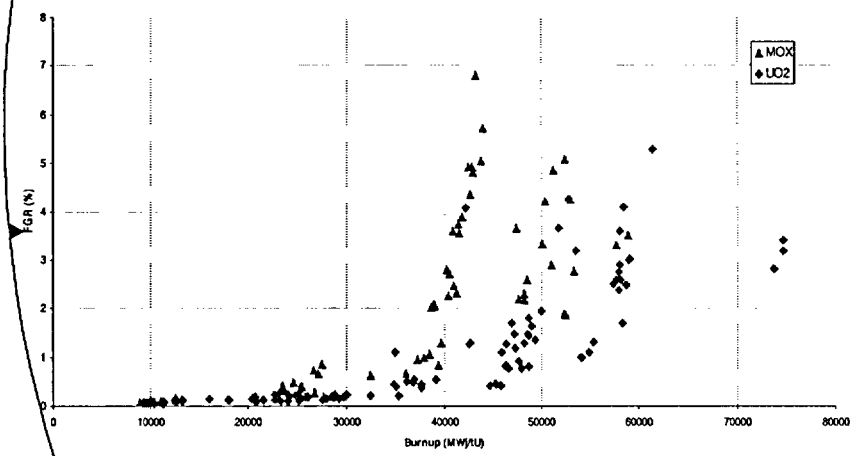
Clad Outer Surface Corrosion (MOX – M5)



MOX / UO_2 Density Evolution with Burnup



FISSION GAS RELEASE OF PWR MOX RODS COMPARED TO UO_2 RODS (EDF DATA)



MOX FUEL DESIGN AND PERFORMANCE

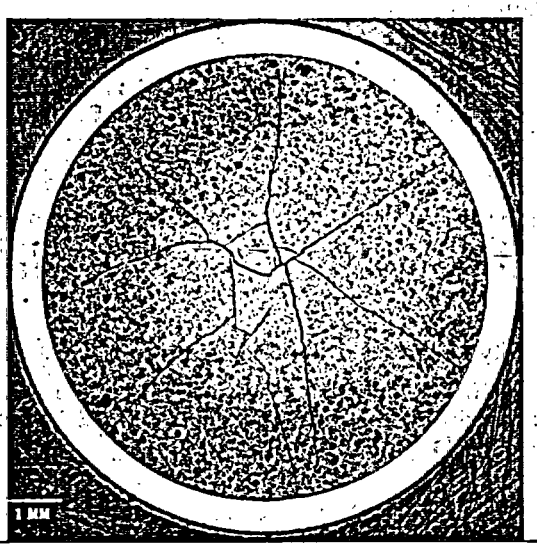
Fission Gas Release Behaviour:

- Neutronic properties: higher linear heat rate at medium/high burnup and different pellet radial power density distribution

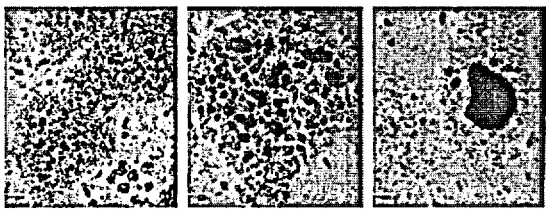
→ higher fuel temperature.

- Physical properties: slightly lower thermal conductivity (centreline temperature increase: 50°C at 200 W/cm), but the BU dependence is the same as for uranium fuel.
- Halden T° threshold: same as UO_2 fuel (function of burnup).
- Oxide microstructure: the presence of Pu-rich particles (30% PuO_2) due to the MIMAS process can change the mechanism of FGR. Local high burnup zones lead to the formation of dense pore populations.

Radial Cut of a MOX Pellet (50 GWd/tM)



EVOLUTION OF THE PELLET MICROSTRUCTURE DURING IRRADIATION



Periphery Mid-radius Centre-line

Burnup = 45 GWd/tM

SHORT AND MEDIUM TERM DEVELOPMENT

▶MOX fuel has to perform as efficiently as UO_2 fuel (burnup and operational flexibility).

▶ The burnup equivalence to uranium FAs has been demonstrated in Germany, Switzerland and Belgium (around 50 GWd/tM).

▶ In France, the UO_2 / MOX "Parity 52" will be completed in 2005: the licensing process is almost completed (for the 20 "MOX" licensed 900 MWe plants). ➔ Rod burnup of 60 GWd/tM

This parity must be established on a long term basis:

▶ - EDF's objective to further increase the UO_2 FA discharge burnup (60 GWd/tM by 2010); the MOX product development is ongoing.

CONCLUSIONS

- Extensive poolside and hot cell examinations have demonstrated the excellent behaviour of MOX fuel up to FA burnup of ~ 58 MWd/kgHM (63 MWd/kgHM rod burnup).

- The performance of the current MOX fuel is equivalent to that of UO_2 fuel in terms of discharge burnup without any penalty on core operating conditions and fuel reliability.

- The ongoing development programmes aim to demonstrate equivalence up to the very high burnups.

AREVA

Mark-BW/MOX1 Fuel Assembly

George Meyer
MOX Fuel Qualification Manager

ACRS Fuels Subcommittee Meeting, April 21, 2004

Mark-BW/MOX1 Lead Assembly

> Lead Assembly Design Description
> Design Evaluation
> Quality Assurance

MOX LTA (Mark-BW/MOX1) Fuel Assembly Design Description

> The MOX Lead Assembly Integrates MOX Pellets into a U.S. Fuel Assembly Design

- Advanced Mark-BW Fuel Assembly
  - The fuel assembly design is presented in BAW-10239, "Advanced Mark-BW Mechanical Design Topical Report"
- European MOX Technology, Experience, and Pellet Design
  - MOX effects are presented in BAW-10238, "MOX Fuel Design Report"

Fuel Assembly Design Features

These design features are identical to those of the Advanced Mark-BW

Fuel Rods

Fuel Rod Parameters	MOX Lead Assembly	Advanced Mark-BW
Clad Material	M5 Alloy	M5 Alloy
Fuel Rod Length, in	152.40	152.16
Cladding OD, in	0.374	0.374
Cladding Thickness, in	0.0225	0.0225
Cladding ID, in	0.329	0.329
Clad-to-Pellet Gap, in	0.0065	0.0065
Fuel Pellet OD, in	0.3225	0.3225
Design Burnup, MWd/Mthm	60,000 Lead Assy 50,000 batch	62,000

Design Evaluation

> Presented in MOX Fuel Design Report
- All requirements of SRP 4.2 are addressed
- Fuel Rod Evaluations use Models Adjusted for MOX
  - Approved methods (for UO_2) with COPERNIC MOX-specific models
    - Models Benchmarked to MOX data, including thermal conductivity, fission gas release, and others as appropriate
- Fuel Assembly Evaluations use Methods Approved for UO_2 Fuel, not affected by the use of MOX Fuel
  - Examples – Stress, Assembly liftoff

Quality Assurance

> MOX Lead Assemblies will be Fabricated under the Framatome ANP Quality Assurance Program
- Meets requirements of 10 CFR Part 50, Appendix B
- Globally implemented within Framatome ANP
- All Suppliers Qualified by Framatome ANP
  - LANL – PuO2 Powder
  - COGEMA Cadarache – MOX Pellets and Fuel Rods
  - COGEMA MELOX – MOX Lead Assemblies
- FANP will provide all non-fuel components
  - Sources are the same as for production FANP UO2 fuel

> Framatome ANP will Certify the Lead Assemblies for delivery to Duke Power

Summary

- > The MOX Lead Assembly Fuel Design Integrates European MOX technology into a US fuel assembly design
- > The design evaluation uses methods that have been approved for LEU fuel and shown to apply to MOX
- > Lead Assembly activities are performed in accordance with the Framatome ANP Quality Management System

MOX Fuel Project
Nuclear Analyses

Jim Eller

Advisory Committee on Reactor Safeguards

April 21, 2004

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MOX MIXED OXIDE FUEL PROJECT

Overview of Presentation

- Analytical models and methodology
  - Studsvik Scandpower core analysis software
- Benchmarking
  - Compare reference data to results from analytical models
  - Power reactor measurements
  - Measurements from experiments
  - Results from theoretical problems
- Catawba 1 Cycle 16 core design containing 4 MOX fuel lead assemblies

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MOX MIXED OXIDE FUEL PROJECT

Analytical Methods

- Duke Power uses Studsvik Scandpower Core Management System (CMS) software
- Various forms of CMS used at Duke since mid 1980s
- Used by 55 organizations in 11 countries to support reactor core design and operation
  - 70 BWRs,
  - 90 PWRs,
  - more than 2000 fuel cycles
    - includes mixed cores containing both mixed oxide and low enriched uranium fuel types

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MOX MIXED OXIDE FUEL PROJECT

Analytical Models

- CASMO-4
  - Two dimensional, multi-group transport theory model
  - Analyze detailed behavior of each unique fuel lattice
- CMS-LINK
  - Collects and tabulates relevant CASMO data
- SIMULATE-3 MOX
  - Three dimensional, two energy group diffusion theory model
  - Includes enhancements to model cores containing LEU and MOX fuels
  - Full or partial core geometries
  - 4 radial nodes per assembly
  - 24 axial levels in the active fuel column
- SIMULATE-3K MOX
  - Extension of SIMULATE model to reactor transients

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MOX MIXED OXIDE FUEL PROJECT

Model Benchmarking and Qualification

- Comparison to power reactor measurements of control rod worth, temperature coefficients, reactivity letdown, and fuel assembly power distribution
  - McGuire & Catawba LEU fuel cycles
  - St Laurent MOX fuel cycles
- Comparison to critical experiments required to address fuel pin by pin power distribution fidelity
  - Saxton multi-region LEU / MOX with 90% Pu-239
  - EPICURE 17x17 PWR lattice, includes AIC and B4C pins
  - ERASME 17x17 PWR lattice, includes various B4C pin configurations
  - B&W LEU experiments

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MOX MIXED OXIDE FUEL PROJECT

Benchmark Results / Conclusions

- The benchmark analyses cover a wide range of reactor materials and conditions
- The results show no significant trends or deficiencies related to MOX fuel modeling
- Detailed numerical results can be found in :
  - Nuclear Design Methodology Using CASMO-4 / SIMULATE-3MOX, Duke Power Company, DPC-NE-1005, August 2001
  - Reactor Core Model Benchmark for Partial MOX Fuel Cycles, Jim Eller, American Nuclear Society Advances in Nuclear Fuel Management Conference, October 2003

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MOX MIXED OXIDE FUEL PROJECT

MOX Lead Assembly Core Design Criteria

- No control rods in MOX fuel assembly in first or second cycle of irradiation
- At least 2 MOX fuel assemblies located in instrumented core locations
  - Preference to use core location C-08 which is fully instrumented in all symmetric core locations
- MOX fuel power peaking must not lead core during nominal depletion
- Demonstrate acceptable margin to MOX specific thermal and mechanical criteria

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MOX MIXED OXIDE FUEL PROJECT

C1C16 Core with MOX Lead Assemblies

	H	G	F	E	D	C	B	A
8	4.70 17 1.364	4.58 104 / 12 18 1.434	4.32 17 1.337	4.85 128 / 16 18 1.357	4.32 17 1.166	4.35 4.13 / 24 48 / 0 1.372	4.33 16 0.972	4.33 16 0.588
9	4.58 104 / 12 18 1.434	4.32 17 1.344	4.70 17 1.411	4.70 17 1.336	4.58 104 / 24 18 1.295	4.70 17 1.292	4.85 48 / 0 18 1.408	4.33 16 0.655
10	4.32 17 1.338	4.70 17 1.411	4.32 17 1.295	4.58 32 / 24 18 1.430	4.32 17 1.229	4.58 80 / 24 18 1.303	4.58 128 / 0 18 1.253	4.63 16 0.627
11	4.85 128 / 16 18 1.357	4.70 17 1.336	4.58 32 / 24 18 1.430	4.32 17 1.283	4.58 16 / 24 18 1.426	4.70 17 1.317	4.85 16 / 0 18 1.434	4.63 16 0.605
12	4.32 17 1.165	4.58 104 / 24 18 1.294	4.32 17 1.230	4.58 16 / 24 18 1.427	4.32 17 1.252	4.85 80 / 0 18 1.428	4.32 17 1.018	
13	4.35 4.13 / 24 48 / 0 1.371	4.70 17 1.292	4.58 80 / 24 18 1.303	4.70 17 1.316	4.85 80 / 0 18 1.426	4.32 17 1.031	4.63 16 0.629	
14	4.33 16 0.974	4.85 48 / 0 18 1.409	4.58 128 / 0 18 1.253	4.85 16 / 0 18 1.433	4.32 17 1.017	4.47 15 0.602		
15	4.33 16 0.584	4.33 16 0.655	4.63 16 0.627	4.63 16 0.604	U235 Enr / Pu Conc LBP Identifier Fuel Batch Number 4 EFPD Peak Pin Power			

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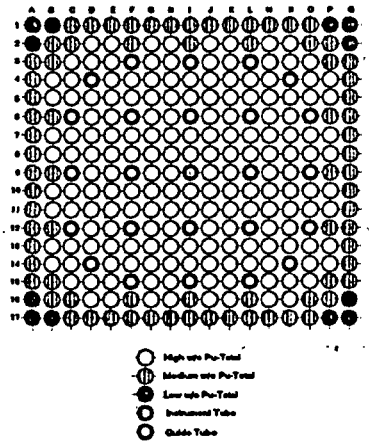
MOX MIXED OXIDE FUEL PROJECT

MOX Fuel Assembly Zoning



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MOX MIXED OXIDE FUEL PROJECT

C1C16 HFP All Rods Out Depletion

			Core Peak Power			MOX Peak Power		
EFPD	PPMB	% AO	Assy	Pin	Fq	Assy	Pin	Fq
0	1859	5.6	1.335	1.447	1.784	1.232	1.402	1.672
4	1414	-1.1	1.330	1.434	1.697	1.208	1.372	1.555
12	1394	-0.5	1.338	1.438	1.691	1.196	1.361	1.542
25	1378	-0.5	1.341	1.434	1.704	1.182	1.345	1.532
50	1365	-0.5	1.344	1.438	1.721	1.164	1.327	1.525
100	1306	-1.0	1.339	1.427	1.712	1.147	1.312	1.513
150	1214	-1.6	1.335	1.419	1.690	1.140	1.306	1.503
200	1099	-2.1	1.348	1.424	1.687	1.138	1.306	1.492
250	962	-2.4	1.354	1.424	1.691	1.139	1.308	1.491
300	808	-2.4	1.360	1.426	1.684	1.142	1.311	1.489
350	639	-2.1	1.367	1.431	1.675	1.148	1.312	1.484
400	458	-1.8	1.370	1.431	1.652	1.153	1.312	1.471
450	273	-1.6	1.368	1.425	1.643	1.159	1.310	1.462
500	86	-1.5	1.357	1.413	1.633	1.164	1.307	1.461
515	30	-1.5	1.353	1.410	1.629	1.165	1.306	1.461
Maximum Exposures								
515			51.3	54.9		22.6	26.8	

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MOX MIXED OXIDE FUEL PROJECT

MOX Lead Assembly Core Design

- Proposed core design is consistent with current fuel management practices
- Places all four MOX assemblies in instrumented core locations
- MOX fuel duty is representative of feed LEU fuel but is not leading the core during nominal depletion
- Normal operating limits will be sufficient to ensure conservative operating margins to MOX specific thermal design criteria

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MOX MIXED OXIDE FUEL PROJECT

MOX Fuel Lead Assembly Safety and Environmental Evaluations

Advisory Committee on Reactor Safeguards – Fuels Subcommittee

NRC Offices - White Flint, MD

Steve Nesbit
Duke Power

April 21, 2004

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MOX MIXED OXIDE FUEL PROJECT

Outline of Presentation

⇒ Key MOX fuel lead assembly characteristics
- Loss of coolant accident (LOCA) analyses
- Non-LOCA evaluations
- Radiological consequences
- Environmental evaluation
- Summary

Key MOX Fuel Lead Assembly Characteristics

- MOX fuel pellets
  - Sintered ceramic oxide [like low enriched uranium (LEU)]
  - Predominantly (>95%) uranium
  - Similar physical characteristics as LEU
- AREVA Advanced Mark-BW/MOX1 design
- MOX fuel decay heat lower than LEU during time frame of interest for transient/accident analyses
- Four MOX fuel assemblies have small impact on global core physics parameters and core radionuclide inventories

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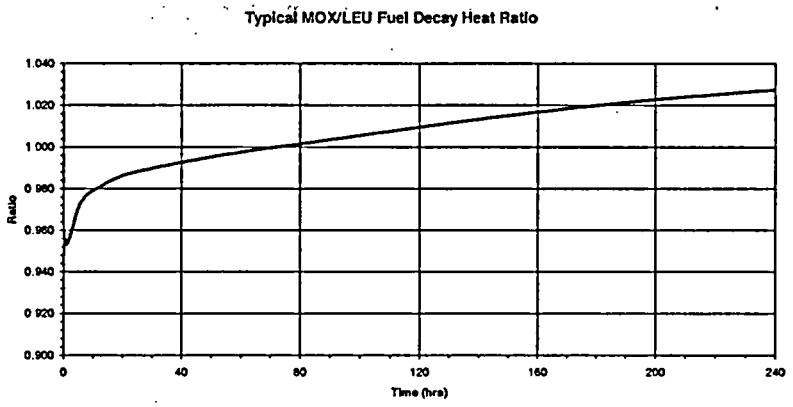
MOX MIXED OXIDE FUEL PROJECT

Decay Heat



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MOX MIXED OXIDE FUEL PROJECT

Global Core Physics Parameters

(% change due to four MOX fuel lead assemblies)

Parameter	BOC (4 EFPD)	EOC (495 EFPD)
Effective delayed neutron fraction	-2.1	-1.0
Prompt neutron lifetime	-1.8	-1.0
Equilibrium xenon worth	-1.1	-0.5
Hot full power mod temp coefficient	-3.0	-0.9
Hot full power Doppler coefficient	-0.7	0

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MOX MIXED OXIDE FUEL PROJECT

Outline of Presentation

- Key MOX fuel lead assembly characteristics
- ⇒ Loss of coolant accident (LOCA) analyses
- Non-LOCA evaluations
- Radiological consequences
- Environmental evaluation
- Summary

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MOX MIXED OXIDE FUEL PROJECT

LOCA Analyses

- Approach - Appendix K large break LOCA evaluation of MOX fuel lead assemblies
- Starting point – approved AREVA evaluation model based on RELAP5/MOD2-B&W
- Potential MOX effects were evaluated and incorporated in evaluation model as appropriate
- A MOX to LEU comparison calculation was performed
- Burnup and axial peaking studies were performed to establish LOCA limits for lead assemblies

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MOX MIXED OXIDE FUEL PROJECT

Potential MOX Effects

Parameter	Effect	LOCA MODEL
1. Thermal Conductivity	Small	MOX used
2. Volumetric Heat Capacity	Essentially none	LEU used
3. Decay Heat	120% of 1971 ANS 5.1 standard plus actinides is conservative	120% of 1971 ANS 5.1 standard plus actinides used
4. Void Reactivity	More negative than LEU	LEU appropriate for core loading
5. Delayed Neutron Fraction	Less than LEU fuel (Conservative for LOCA)	LEU appropriate for core loading

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MOX MIXED OXIDE FUEL PROJECT

MOX Fuel Assembly Radial Zoning

- MOX fuel assemblies use pins of three different plutonium concentrations in order to flatten radial power
- MOX LOCA analysis modeled all three concentrations (2.3% Pu -5% Pu)
- No significant impact of Pu concentration on peak cladding temperature
  - Within 1°F over range of concentrations

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MOX MIXED OXIDE FUEL PROJECT

Stylized MOX/LEU Comparison Analysis

Parameter (Time-In-Life)	LEU (0 GWd)	MOX (0 GWd)
Total Peaking (Fq)	2.4	2.4
PCT (F) Pin #1 (2.3 % Pu)	1981	2018

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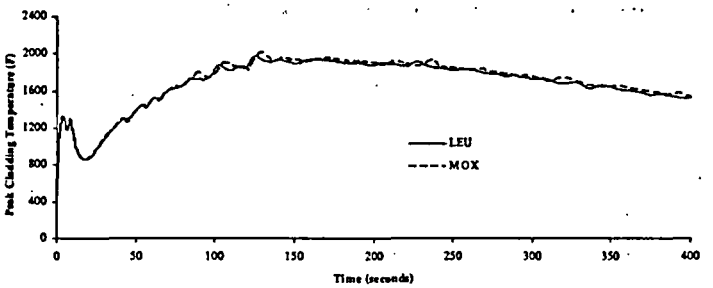
MOX MIXED OXIDE FUEL PROJECT

MOX/LEU Comparison



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MOX MIXED OXIDE FUEL PROJECT

Sensitivity Studies

- Steam generator design
- Time-in-life
- Location of axial peak
- End-of-cycle coolant temperature reduction

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MOX MIXED OXIDE FUEL PROJECT

Other Criteria and Evaluations

- All 10 CFR 50.46 criteria are met for large break LOCA
  - Peak cladding temperature
  - Maximum cladding oxidation
  - Maximum hydrogen generation
  - Coolable geometry
  - Long-term cooling
- Small break LOCA
  - Not limiting for Catawba
  - MOX/LEU differences insignificant
- No adverse MOX impact on uranium fuel (no mixed core penalty)

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MOX MIXED OXIDE FUEL PROJECT

MOX Fuel Relocation During LOCA

- Fuel relocation during LOCA identified as Generic Safety Issue (GSI) 92 in 1980s, dropped in 1998
- 10/23/03 IRSN presentation on proposed PHEBUS tests mentioned fuel relocation during LOCA and MOX fuel
  - Higher MOX power at EOC (p. 21)
  - Filling ratio of "balloon" – MOX agglomerates effect (p. 22)?
  - Bigger "balloons"/blockage with modern alloys like M5 (p. 24)
- Intervener assertion that NRC should deny application due to these unknowns

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MOX MIXED OXIDE FUEL PROJECT

MOX Fuel Relocation During LOCA

- Confusion about LOCA effect vs. severe accident effect
  - IRSN noted that fuel relocation occurred at lower temperature in VERCORS RT2 test (MOX) than in RT1 test (LEU)
  - RT2 relocation occurred at severe accident conditions, not LOCA
- MOX fuel lead assembly power lower than peak LEU fuel assembly power throughout cycle
- No quantification made of postulated MOX agglomerate effect (or LEU RIM effect) on "filling size"
- Blockage due to ballooning of M5 cladding was evaluated at most ductile (unirradiated) conditions and found acceptable

LOCA Summary

- Specific evaluations were performed for MOX fuel lead assemblies using conservative Appendix K models appropriately adjusted for MOX fuel
- Analysis results were fundamentally similar to uranium fuel
- Sensitivity studies were performed on plant operating conditions
- Peaking criteria were established that ensure that MOX fuel remains within 10 CFR 50.46 acceptance criteria

Outline of Presentation

- Key MOX fuel lead assembly characteristics
- Loss of coolant accident (LOCA) analyses

⇒Non-LOCA evaluations

- Radiological consequences
- Environmental evaluation
- Summary

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MOX MIXED OXIDE FUEL PROJECT

Non-LOCA Evaluations

- Plant response to most non-LOCA design basis events is driven by global core physics parameters, system thermal-hydraulics, stored energy, and decay heat
  - MOX fuel impact on global physics parameters is typical of cycle-to-cycle variations
  - System thermal-hydraulics are unaffected by MOX fuel
  - Four MOX fuel assemblies have no appreciable impact on stored energy
  - Decay heat is lower for MOX fuel during the time period of interest for transient analysis
- Some events require more detailed evaluation due to the potential for local effects

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MOX MIXED OXIDE FUEL PROJECT

Control Rod Misoperation / Steam Line Break

- MOX fuel lead assemblies will not be placed under control rods during first two cycles
- Control rod withdrawal or drop
  - Rodded location is limiting
  - MOX fuel not in rodded location
- Steam line break
  - Rodded location is limiting (adverse peaking during return to power in core location with assumed most reactive control rod stuck out of core)
  - MOX fuel not in rodded location

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MOX MIXED OXIDE FUEL PROJECT

Control Rod Ejection

- Cabri tests indicate that lower fuel enthalpy (cal/g) criterion may be appropriate for MOX fuel
  - Duke proposed 100 cal/g acceptance criterion for lead assemblies
  - Well below Cabri Rep Na-7 failure (125 cal/g)
- SIMULATE-3K MOX code (3D kinetics) used to simulate conservative control rod ejection scenarios in a representative core
  - Maximum MOX fuel enthalpy following hot zero power control rod ejection was less than 50 cal/g
  - Duke will perform cycle-specific analysis to confirm acceptable values

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MOX MIXED OXIDE FUEL PROJECT

Fuel Assembly Misloading

- Administrative measures are equally effective for MOX fuel as for LEU fuel
- Misloading would be even more apparent in flux maps taken during power escalation testing
  - MOX fuel has significantly lower thermal flux than LEU fuel for the same power level
  - MOX fuel lead assemblies will be preferentially loaded in instrumented locations

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MOX MIXED OXIDE FUEL PROJECT

Non-LOCA Summary

- The impact of four MOX fuel lead assemblies on most non-LOCA design basis events is clearly negligible
  - Similar fuel design
  - Lower decay heat
  - Impact on global physics parameters in the noise of reload design
- Events with potential local effects were evaluated in more detail
  - Attributes of lead assembly program obviate most potential issues
  - Cycle-specific rod ejection analyses

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MOX MIXED OXIDE FUEL PROJECT

Outline of Presentation

- Key MOX fuel lead assembly characteristics
- Loss of coolant accident (LOCA) analyses
- Non-LOCA evaluations
- ⇒ Radiological consequences
- Environmental evaluation
- Summary

Radiological Consequences

- SCALE analyses show that fission product inventories are similar between MOX fuel and LEU fuel
  - Worst case ^{131}I may be as much as 9% higher in a MOX fuel assembly compared to an equivalent LEU fuel assembly
  - Potential impact on thyroid and TEDE doses
- Accidents involving numerous fuel assemblies should see no significant impact
  - LOCA, rod ejection, and locked rotor assumed to fail 11%-100% of the fuel in the core
  - Lead assemblies are only 2% of the core
  - Postulated failures in non-MOX fuel assemblies dominate impacts

Radiological Consequences (cont.)

- Maximum impact seen in postulated accidents involving one or a just a few assemblies
  - Fuel handling accident (FHA) (one assembly)
  - Weir gate drop (WGD) (seven fuel assemblies)
- Explicit FHA and WGD calculations performed using Alternate Source Term methodology
  - MOX fuel-specific radionuclide inventories
  - Sensitivity study - Reg Guide 1.183 gap gap fractions increased 50% to reflect higher fission gas release from MOX fuel
- Offsite and control room doses ~60% higher than all-LEU fuel case, but still well within regulatory limits

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MOX MIXED OXIDE FUEL PROJECT

MOX/LEU Dose Comparison (Weir Gate Drop)

Receptor	TEDE Dose Limit (Rem)	LEU Fuel (Rem)	MOX Fuel – Nominal Release Fractions (Rem)	MOX Fuel – +50% Gas Release Fractions (Rem)
EAB	6.3	2.2	2.3	3.5
LPZ	6.3	0.31	0.33	0.50
Control Room	5.0	2.1	2.2	3.3

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MOX MIXED OXIDE FUEL PROJECT

Radiological Consequences Summary

- Potential for dose impacts
  - Different radionuclide inventories
  - Higher fission gas release from MOX fuel
  - Greatest impact for accidents involving a small number of assemblies
- Explicit analyses of fuel handling and weir gate drop accidents
  - Conservative treatment of MOX/LEU differences
  - Alternative Source Term methodology
  - Higher consequences in MOX fuel analyses, but well within regulatory limits

Outline of Presentation

- Key MOX fuel lead assembly characteristics
- Loss of coolant accident (LOCA) analyses
- Non-LOCA evaluations
- Radiological consequences

⇒ Environmental evaluation

- Summary

Environmental Evaluation

- Assessment of potential MOX fuel lead assembly impacts on the environment
- Normal operations
  - No impact on effluents
  - Slight increase in fuel handling occupational dose
- Accident situations addressed in safety analyses and radiological consequence analyses

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MOX MIXED OXIDE FUEL PROJECT

Severe Accidents with MOX Fuel Lead Assemblies

- Addressed in environmental report
- Evaluation based on Department of Energy analysis of the impact of 40% MOX fuel cores on severe accident consequences
  - 1999 Surplus Plutonium Disposition Environmental Impact Statement
  - Four sequences considered
  - MOX-specific radionuclide inventories
  - Results scaled from 40% MOX fuel cores to lead assembly cores (2% MOX fuel)

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MOX MIXED OXIDE FUEL PROJECT

Severe Accident Impacts

- Assumptions
  - Four MOX fuel lead assemblies in four separate core quadrants have no significant impact on severe accident progression
  - LEU release fractions are representative of MOX fuel
- Scaled Catawba lead assembly results
  - Change in consequences relative to all-LEU core range from -0.2% to +0.7%
  - Worst case was the dose to the maximally exposed individual following an interfacing systems LOCA
- Lyman analysis of MOX fuel cores (2000)
  - Maximum increase in consequences 1.3% (scaled from 40% MOX fuel core to four lead assemblies) for very early containment failure scenario
  - Sensitivity study with maximum actinide release fractions produced 1.6% increase (scaled)

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MOX MIXED OXIDE FUEL PROJECT

Severe Accident Issues

- No significant change in core melt probability due to four MOX fuel lead assemblies
  - Core melt probability driven by factors unrelated to fuel, e.g., equipment availability
  - Lead assemblies involve no change in plant design
- No significant change in severe accident progression due to four MOX fuel lead assemblies
  - Physical characteristics of MOX fuel are very similar to LEU fuel
  - Accident progression driven by LEU fuel (98% of the core)

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MOX MIXED OXIDE FUEL PROJECT

Severe Accident Issues (cont.)

- Radionuclide Inventories
  - MOX-specific inventories explicitly calculated in DOE and Lyman studies
- Source Term Release Fractions
  - Addressed by expert panel in NRC-sponsored report ERI/NRC 02-202
    - Postulated some differences relative to NUREG-1465 LEU
    - Similar to differences postulated for high burnup pressurized water reactor fuel relative to NUREG-1465
  - VERCORS tests on MOX fuel

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MOX MIXED OXIDE FUEL PROJECT

Severe Accidents - Summary

- Severe accident behavior will be driven by LEU fuel
- Any impact from MOX fuel lead assemblies (2% of the core) would be negligible compared to overall uncertainties in light water reactor severe accident behavior
- DOE analyses indicate maximum adverse impact of +0.7%
- Lyman analyses (with worst-case actinide release fractions) indicate maximum adverse impact of +1.6%

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MOX MIXED OXIDE FUEL PROJECT

Outline of Presentation

- Key MOX fuel lead assembly characteristics
- Loss of coolant accident (LOCA) analyses
- Non-LOCA evaluations
- Radiological consequences
- Environmental evaluation

⇒ Summary

The Big Picture

- All nuclear power reactors are already using Pu fuel
  - About 850 kg plutonium in Catawba LEU core at end of cycle (compared to ~80 kg in four lead assemblies)
  - About 50% core power from plutonium fissions at end of cycle
- A similar MOX fuel lead assembly program was safely conducted at Ginna in the early 1980s
- European nuclear power reactors have demonstrated the safety of using MOX fuel
  - More than thirty reactors in four countries over 25 years
  - Up to 36% core fractions
- This program - 4 assemblies out of 193 (2.1% of core)

Conclusion

- Duke license amendment request addressed potential MOX fuel lead assembly impacts on normal operations, the full range of design basis events, and severe accidents
- Regulatory limits are met
- No significant hazard to the public

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MOX
MIXED OXIDE FUEL PROJECT

NRC STAFF REVIEW OF USE OF MIXED OXIDE LEAD TEST ASSEMBLIES AT CATAWBA NUCLEAR STATION

Robert E. Martin, Senior Project Manager
Undine Shoop, Reactor Systems Engineer
Ralph Landry, Senior Reactor Engineer
Steve La Vie, Health Physicist

Presentation for the
Advisory Committee on Reactor Safeguards
April 21, 2004

Presentation Message

- Licensee's Application of February 27, 2003, Followed by Numerous Supplements by Licensee.
- NRC Staff Safety Evaluation of April 5, 2004.
- NRC Staff radiological Safety Evaluation found use of MOX LTAs acceptable on the basis of evaluations presented in that Safety Evaluation.
- Approval of application requires completion of other matters.
- Issue of Next Generation Fuel addressed by Licensee's letter of April 16, 2004, is under NRC staff review.

Catawba MOX LTA LOCA

Ralph R. Landry
Reactor Systems Branch, NRR
April 21, 2004

MOX LTA LOCA

- Analysis of Record
- Resident Fuel
- MOX LTA
- LOCA Effect

MOX LTA LOCA

- Analysis of record is Westinghouse WCOBRA/TRAC Realistic LBLOCA
- Resident fuel assemblies are Westinghouse Robust Fuel Assemblies (RFA)
- MOX LTAs are Framatome ANP Mark-BW/MOX1

MOX LTA LOCA

- Analysis of record covers Mark-BW fuel by sensitivity study use of a surrogate, or proxy, assembly with pressure drop representative of Mark-BW assembly
- Mark-BW/MOX1 assembly pressure drop is closer to Westinghouse RFA than to Mark-BW fuel

MOX LTA LOCA

- MOX LTA LOCA response calculated using Framatome ANP Appendix K code, RELAP5/MOD2-B&W
- Approved code includes approved properties of M5 cladding

MOX LTA LOCA

- Decay heat model used, ANSI/ANS-5.1-1994, is applicable since highly burned LEU fuel produces the majority of its energy from the fission of plutonium. Multiplier of 1.2 is used to cover uncertainties (Figure 3-3)

MOX LTA LOCA

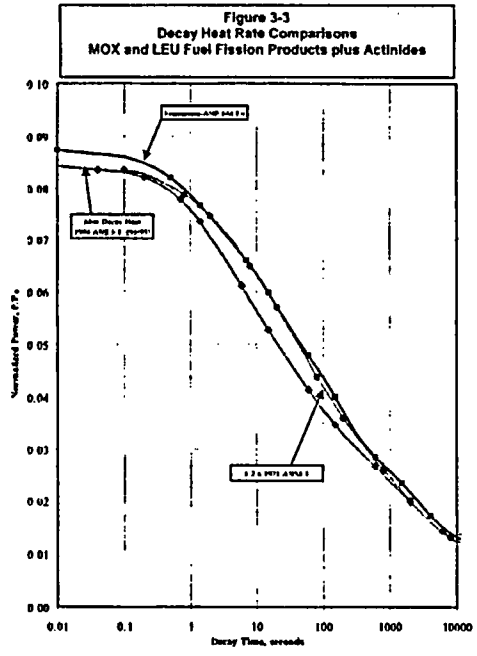
Figure 3-3
Decay Heat Rate Comparisons
MOX and LEU Fuel Fission Products plus Actinides
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
0.01
0.1
1
10
100
1000
10000

MOX LTA LOCA

- DPCT for MOX LTA vs. RFA LEU is -38°F, or 2018°F for the MOX LTA vs. 2056°F for the RFA LEU
- MLO for MOX LTA is 4.5% vs. RFA 10%
- MOX LTA placement is in non-limiting locations

MOX LTA LOCA

- Staff concludes that MOX LTAs will comply with requirements of 10 CFR 50.46 when inserted in core of Westinghouse RFA LEU fuel

Review of Design Basis Accident Radiological Consequences of Mixed Oxide Lead Test Assemblies

Stephen F. LaVie
Probabilistic Safety Assessment Branch

Review Scope

- Acceptance Criteria
  - 10 CFR 100.11
  - 10 CFR Part 50 GDC-19
  - 10 CFR 50.67 (Fuel Handling Accident only)
- Review
  - Reviewed licensee documentation; performed confirmatory calculations
- Conclusion
  - Negligible impact on prior analysis results; doses continue to meet acceptance criteria.

Licensee's Analysis Approach

- Divided existing UFSAR analyses into two categories:
  - MOX LTAs are a large fraction of the affected fuel assemblies:
    - *Fuel handling accident, weir gate drop accident*
    - *Re-calculated dose consequences*
  - MOX LTA are a small fraction of the affected fuel assemblies:
    - *LOCA, locked rotor accident, rod ejection accident*
    - *Scaled prior doses for change in inventory, gap fraction*
- Analyzed fresh fuel drop event

Staff Review

* Staff confirmed licensee's MOX LTA fission product inventory
  * Comparison to ORIGEN-2.2 results generated by Sandia using MOX cross-section libraries
  * Staff independent SAS2H/ORIGEN-S calculations, based on proposed MOX LTA configuration
  * Results showed that iodines increased, kryptons decreased, most xenons increased, cesium increased
  * I-131 increase was about 9 %
  * Licensee's values bounded Sandia and staff values for dose-significant (for DBAs) nuclides

Staff Review

- Staff confirmed licensee's gap fraction assumptions.
  - RES with assistance of PNNL performed a fission gas release analysis of the MOX LTAs
  - Evaluation based on FRAPCON-3.2, which has been benchmarked against a database of MOX fuel rods.
  - Massih model in FRAPCON was used to estimate the stable noble gas FGR
  - ANS-5.4 model (with adjusted inputs) was used to obtain radioactive fission gas release estimates
  - Rod pressurization continues to meet limitation for crediting FHA pool iodine decontamination.

MOX LTA Gap Fractions

	RG 1.183 (LEU)	Licensee Assumption	Staff Evaluation
I-131	0.08	0.12	0.095 - 0.105
Kr-85	0.10	0.15	0.144 - 0.168
Other halogens; noble gases	0.05	0.075	0.075
Alkali Metals	0.12	n/a	0.191 - 0.226

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USE OF MIXED-OXIDE LEAD TEST ASSEMBLIES AT CATAWBA

Presentation to ACRS Reactor Fuels Subcommittee

Edwin Lyman
Union of Concerned Scientists
April 21, 2004

Union of Concerned Scientists

DUKE MOX LTA APPLICATION

- On 2/27/03, Duke Energy filed a license amendment request (LAR) to use four MOX lead test assemblies (LTAs) at either Catawba or McGuire (later restricted to Catawba only)
- On 9/15/03, Duke filed a "Request for Exemption from Certain Regulatory Requirements in 10 CFR 11 and 73 to Support MOX Fuel Use"

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BREDL INTERVENTION ON MOX LTA REQUEST

- UCS is assisting the Blue Ridge Environmental Defense League (BREDL) in its challenge of Duke's MOX LTA LAR and security exemption request
- Security-related contentions
  - conducted in closed (safeguards) proceeding
- Non-security-related contentions (safety and environmental)

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MOX LTA HEARING

- ASLB admitted three (reframed) non-security-related contentions on 3/5/04
- Duke wants NRC to issue the LTA license amendment and security exemptions by early August 2004
  - Timetable is driven by DOE/NNSA's desire for a decision prior to shipment of plutonium to France for LTA fabrication at Cadarache (before plant shuts down)
  - ASLB attempt to accommodate this request is resulting in a highly compressed adjudicatory proceeding

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WHAT'S THE RUSH?

- But in every other respect, the U.S.-Russian MOX program is proceeding at a glacial pace:
  - Failure to reach agreement on liability for Russian program
  - Failure to raise sufficient funds for Russian program
  - Failure to conclude agreement on monitoring and inspections
  - Substantial delays in completion of US MOX fabrication plant design due to sudden changes in program direction by NNSA

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MOX LTAs: THE BIG PICTURE

- Approvals of MOX LTA LAR and security exemptions will set precedents for future batch MOX loading
- US approval process for MOX LTA LA and security exemptions will set an example for Russian counterpart
- Ability of NNSA to ship Pu to France is unaffected by NRC decisions
- Why not take the time to do a thorough review?

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DUKE SECURITY EXEMPTION REQUEST

- 9/15/03 security exemption request:
  - Rationale: Several requirements in 10 CFR §73.45 and §73.46 are "impractical and unnecessary to assure the security of any MOX fuel assemblies"
  - These sections pertain to physical protection systems for protecting formula ("Category I") quantities of strategic special nuclear material from the design basis threats of theft and sabotage
  - Details are provided in seven attachments, much of which NRC has determined contains Safeguards Information

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SECURITY EXEMPTION REQUEST (cont.)

- "Duke Power maintains that ... its security request is reasonable, given the difficulty of diverting plutonium contained in the bulky fuel rods ..." --- "Nuclear Security Decisions are Shrouded in Secrecy," R. Jeffrey Smith, The Washington Post, March 29, 2004.

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NRC MOX LTA SECURITY REVIEW PLAN

- Earlier this year, NRC publicly released a plan providing guidance to NRC staff who will perform safeguards and security reviews of license applications to possess and use MOX fuel in a power reactor (memo from J. Shea to G. Tracy, January 29, 2004)

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MOX SECURITY REVIEW PLAN (cont.)

- "...the staff's assessment is that the MOX material, while meeting the criteria of a formula quantity, is not attractive to potential adversaries from a proliferation standpoint due to its low plutonium concentration, composition and form."
- "A large quantity of MOX fuel and an elaborate extraction process would be required to accumulate enough material to fabricate an improvised nuclear device or weapon."
- Cites 1989 exemption from Category I requirements for fresh fuel containing highly enriched uranium for the Fort St. Vrain gas-cooled reactor

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FLAWS IN MOX SECURITY REVIEW PLAN

- Assertion that MOX assemblies require less protection than plutonium is inconsistent with
  - International Convention on Physical Protection
  - IAEA guidance INFCIRC/225 (Rev. 4)
  - U.S.-Russian Plutonium Disposition Agreement
  - National Academy of Sciences recommendation ("stored weapons standard")
- Fort St. Vrain security exemption has little relevance to the MOX exemption request
  - SNM content much lower than in a MOX assembly
  - Extracting HEU from GCR fuel much harder than separating Pu from a MOX assembly

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CONTENTION I

- Reframed (Non-security) Contention I: Duke has failed to adequately account for differences in MOX and LEU fuel behavior with regard to LOCAs and other DBAs
- Issues:
  - Fuel-related phenomena that may affect compliance with ECCS criteria for MOX LTAs
  - M5 cladding-related phenomena that may affect compliance with ECCS criteria for MOX LTAs
- Fundamental problem: Uncertainties due to gaps in experimental database for MOX under LOCA conditions
  - IRSN proposal for Phébus MOX DB-LOCA test

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FUEL RELOCATION DURING LOCA

- Temperature effect of fuel relocation during a LOCA (collapse of fuel fragments following clad ballooning) not considered in Appendix K
- IRSN: Fuel relocation may
  - Increase peak cladding temperature (PCT) by more than 100°C (180°F)
  - Increase local clad oxidation by 5 to 10%
- Taking relocation into account may be more important for M5-clad MOX than for LEU
  - lower margin for MOX (higher temperature)
  - M5 forms bigger balloons (greater ductility)

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FUEL RELOCATION

- Results of Duke large-break LOCA calculation from LAR
  - PCT: 2018°F for MOX; 1981°F for LEU
- An increase of 180 degrees F from relocation effects would bring the MOX PCT to just under the regulatory PCT limit of 2200°F

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M5 CLADDING ISSUES

- Vulnerability of zirconium-niobium alloy claddings (E110, M5) to embrittlement appears to be a function of initial surface treatment (polishing vs. etching)
  - Argonne oxidation test on etched M5 samples "showed a potential similarity to the oxide characteristics of alloy E-110" — letter from James F. Mallay, Framatome ANP, to Ralph Meyer, RES, May 5, 2003;
  - Raises questions regarding stability of M5 with respect to production conditions, changes under irradiation, corrosion, hydrogen uptake (see Updated Program Plan for High-Burnup LWR Fuel)

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CONTENTION II

- Reframed (Non-security) Contention II: Duke has failed to adequately account for differences in MOX and LEU fuel behavior with respect to radionuclide releases during "core disruptive accidents"
- Issues (see Expert Panel Report on High-Burnup and MOX Source Terms, ERI/NRC 02-0202, Nov. 2002):
  - Different degradation behavior of MOX
  - Enhanced release rates of some radionuclides from MOX
  - Current source term underestimates release fractions of tellurium and ruthenium isotopes (inventories greater in MOX)
- Fundamental problem: Uncertainties due to gaps in experimental database for MOX under core melt conditions
  - IRSN proposal for Phébus MOX source term test

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CONCLUSIONS

- Much research is needed to reduce the uncertainties in M5 cladding and MOX fuel performance
  - ANL LOCA tests with irradiated M5-clad fuel LEU
  - Halden fuel relocation test (LEU)
  - Proposed Phébus LOCA and source term tests (MOX)
- BREDL/UCS maintains that experimental data is insufficient to support approval of Duke's MOX LTA LAR at this time
- Duke has not adequately demonstrated that the introduction of 4 MOX LTAs will have only an insignificant impact on risk

SRXB Review of the Mixed Oxide Fuel Lead Test Assemblies

Meeting with ACRS Fuels Subcommittee
April 21, 2004

Undine Shoop
U.S. Nuclear Regulatory Commission

Purpose

- Discuss Areas of Staff Review
  - Thermal Mechanical Design
  - Data Collection
  - Nuclear Design
  - Non-LOCA Transient Analysis
  - LOCA

Thermal Mechanical Design

Undine Shoop

Fuel Assembly Design

- Lead Test Assembly (LTA)
  - Licensing framework is SRP Section 4.2
- Design Evaluation is provided in BAW-10238

SRP Section 4.2 Objectives

- Fuel system is not damaged as a result of normal operation and anticipated operational occurrences
- Fuel system damage is never so severe as to prevent control rod insertion when it is required
- Number of fuel rod failures is not underestimated for postulated accidents
- Coolability is always maintained

MOX Fuel Design Report

- MOX design considerations
- Weapons-grade plutonium
- Thermal/mechanical fuel assembly analysis
  - An audit was performed of these calculations
- Experience Database
- Lead assembly test program

Framatome MOX vs LEU Fuel Assembly Design Differences

- Longer fuel rod
- European dish and chamfer designs
- 95% theoretical density
- Use of Mixed Oxide for fissile material

Mixed Oxide Fuel

- Depleted Uranium matrix with weapons grade Plutonium fissile material
- Significance of Isotopic Mixture
  - Fewer absorbers isotopes
  - Increased fissile isotopes
  - Lower enrichment requirement for comparable reactivity than reactor grade MOX

Gallium

- Has the potential to migrate to the cladding and embrittle the cladding
  - Removed through polishing
  - ORNL tests on gallium migration
  - 300 ppb limit for plutonium feed material

Data Collection Program

Undine Shoop

Data Collection Program

- Purposes
  - Neutronic – Startup Physics Testing
  - Fuel Behavior – Post Irradiation Examinations (PIEs)

Neutronic

- 2 LTAs will be located in core locations that are directly measured by movable in-core detectors for the first and second irradiation cycles
- Operating Data from the cycle
  - Measurements taken monthly
  - Used to verify CASMO-4/SIMULATE-3MOX

Neutronic - continued

- Start up Physics Test Plan
  - Critical boron concentration (both at HZP and >90% full power)
  - Isothermal temperature coefficient
  - Bank worth measurements
  - Low power flux map
  - Intermediate flux map
  - High power flux map

Poolside PIE

- Performed between cycles
  - Visual inspection of both the fuel assembly and fuel rods
  - Fuel assembly growth
  - Fuel rod growth
  - Fuel assembly bow

Poolside PIE - continued

- Performed after assembly discharge
  - Grid width
  - Fuel rod oxide thickness
  - Grid oxide thickness
  - RCCA drag force
  - Guide thimble plug gauge
  - Water channels (fuel rod bowing)

Hot Cell PIE

- Rod puncture
- Metallography/ Ceramography
- Cladding Mechanical Tests
- Burnup Analysis
- Burnup Distribution

Nuclear Design

Undine Shoop

Neutronic Impact of LTAs

- 4 LTAs and 189 other assemblies
- Insignificant impact on core wide neutronic behavior

Core Design

- Checkerboard Pattern
- LTAs in symmetric core locations
- Unrodded locations
- LTAs are not limiting, but are in prototypical locations

Core Sensitivity Studies

- Duke performed studies of LEU and MOX LTA core
- Investigated important core parameters

Key Core Wide Physics Parameters

- Critical boron concentration
- Control rod worths
- Moderator coefficient
- Fuel temperature coefficient

Key Core Physics Parameters

EFPD	POWER (percent)	BORON (ppm)			MAX ASSY POWER 2RPF			2-D PEAK PIN POWER 2PIN		
		MOX	LEU	DELTA	MOX	LEU	DELTA	MOX	LEU	DELTA
0	0	1832	1815	17	1.407	1.334	0.073	1.557	1.498	0.059
4	100	1242	1235	7	1.291	1.284	0.007	1.426	1.423	0.003
12	100	1224	1218	6	1.272	1.277	-0.005	1.411	1.418	-0.007
25	100	1234	1230	4	1.272	1.275	-0.003	1.416	1.420	-0.004
50	100	1260	1258	2	1.270	1.270	0.000	1.421	1.421	0.000
100	100	1249	1250	-1	1.321	1.317	0.004	1.401	1.397	0.004
150	100	1170	1173	-3	1.345	1.340	0.005	1.414	1.409	0.005
200	100	1046	1051	-5	1.357	1.353	0.004	1.430	1.425	0.005
250	100	892	898	-6	1.373	1.365	0.008	1.437	1.431	0.006
300	100	720	728	-8	1.375	1.366	0.009	1.435	1.425	0.010
350	100	537	545	-8	1.361	1.354	0.007	1.420	1.413	0.007
400	100	350	359	-9	1.339	1.332	0.007	1.395	1.388	0.007
450	100	164	173	-9	1.313	1.307	0.006	1.368	1.362	0.006
470	100	91	100.	-9	1.302	1.297	0.005	1.357	1.351	0.006
490	100	19	28	-9	1.293	1.289	0.004	1.347	1.342	0.005
495	100	1	10	-9	1.291	1.287	0.004	1.344	1.340	0.004

Key Core Physics Parameters

	EFPD	POWER (percent)	BETA-EFFECTIVE	DELTA	PROMPT NEUTRON LIFETIME	DELTA
MOX	4	100	0.00609		15.74	
LEU	4	100	0.00622	-0.00013	16.03	-0.29
MOX	495	100	0.00504		19.57	
LEU	495	100	0.00509	-0.00005	19.76	-0.19

Key Core Physics Parameters

EFPD	POWER (percent)	BORON (ppmb)	ITC (pcm/°F)			MTC (pcm/°F)		
			MOX	LEU	DELTA	MOX	LEU	DELTA
0	100	1832	-8.48	-8.05	-0.43	-7.03	-6.60	-0.43
0	0	1832	-3.47	-3.10	-0.37	-1.76	-1.40	-0.36
4	100	1242	-13.84	-13.47	-0.37	-12.40	-12.04	-0.36
4	0	1242	-8.15	-7.85	-0.30	-6.46	-6.18	-0.28
200	100	1046	-18.34	-17.95	-0.39	-16.85	-16.47	-0.38
200	0	1046	-10.90	-10.60	-0.30	-9.18	-8.89	-0.29
495	100	1	-37.56	-37.25	-0.31	-35.92	-35.61	-0.31
495	0	1	-26.47	-26.25	-0.22	-24.66	-24.43	-0.23

EFPD	POWER (percent)	BORON (ppmb)	DOPPLER (pcm/°F)			DIFF BORON WORTH (pcm/ppm)		
			MOX	LEU	DELTA	MOX	LEU	DELTA
0	100	1832	-1.45	-1.45	0.00	-6.19	-6.30	0.11
0	0	1832	-1.71	-1.70	-0.01	-6.54	-6.68	0.14
4	100	1242	-1.44	-1.43	-0.01	-6.30	-6.40	0.10
4	0	1242	-1.69	-1.67	-0.02	-6.66	-6.78	0.12
200	100	1046	-1.49	-1.48	-0.01	-6.49	-6.56	0.07
200	0	1046	-1.72	-1.71	-0.01	-6.82	-6.89	0.07
495	100	1	-1.64	-1.64	0.00	-7.94	-8.01	0.07
495	0	1	-1.81	-1.82	0.01	-8.28	-8.35	0.07

Note: Boron concentrations in this table are for a representative core with MOX fuel lead assemblies. Table 3-7 has the corresponding boron concentrations for an all-LEU core.

Assembly Physics Parameters

- Reduced delayed neutrons
- Increased void reactivity effect
- Prompt neutron lifetime

Non – LOCA Transients

Undine Shoop

Non-LOCA Transients

- Deterministic Licensing application - addresses Chapter 15 transients
- Normal reload process used
- Confirm that all physics parameters fall within reference values previously calculated

Transients Most Affected by the Physics

- Control Rod Ejection
- Rod Cluster Control Assembly Misoperation
- Steam System Piping Failure
- Fuel Assembly Misloading

Control Rod Ejection

- Core loading Pattern precludes significant impact of RIA
  - LTAs in unrodded locations
  - LTAs not close to fuel assemblies having significant ejected control rod worth
- Peak LEU enthalpy of 54 cal/g
- Peak MOX enthalpy of 30 cal/g

Rod Cluster Control Assembly Misoperation

- MOX LTAs in unrodded location during the first cycle and in non-limiting locations
- Reactivity of MOX LTAs and control rod worth for any rodded LTA during the second and third cycles will be below the limiting values

Steam System Piping Failure

- Accident performed with most reactive rod stuck out
- LTAs are unrodded so will not impact the most reactive rods' worth

Fuel Assembly Misloading

- Administrative measures
- Core power distribution measurements