Official Transcript of Proceedings

NUCLEAR REGULATORY COMMISSION

Title:	Advisory Committee on Reactor Safeguards Subcommittee on Future Plant Design [Advanced Reactor Designs]
Docket Number:	(not applicable)
Location:	Rockville, Maryland
Date:	Monday, July 8, 2002

Work Order No.: NRC-456 Pages 1-361

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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

SUBCOMMITTEE ON FUTURE PLANT DESIGN

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MONDAY,

JULY 8, 2002

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ROCKVILLE, MARYLAND

The Subcommittee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 8:30 a.m., Thomas S. Kress, Chairman, presiding.

SUBCOMMITTEE MEMBERS:

THOMAS S. KRESS, Chairman
MARIO V. BONACA, Member
F. PETER FORD, Member
GRAHAM M. LEITCH, Member
VICTOR H. RANSOM, Member
STEPHEN L. ROSEN, Member
JOHN D. SIEBER, Member
GRAHAM B. WALLIS, Member

ACRS STAFF PRESENT:

MEDHAT EL-ZEFTAWY

ALSO PRESENT:

CHARLES ADER - RES
SYED A. ALI - RES
STEVEN ARNDT - RES
PEGGY BENNETT - RES
SHANA BROWDE - RES
DONALD CARLSON - RES
MARY DROUIN - RES
FAROUK ELTAWILA - RES
JOHN H. FLACK - RES
CHARLES GREENE - RES
JOEL KRAMER - RES
RICHARD Y. LEE - RES
PAUL LEWIS - RES
JOCELYN MITCHELL - RES
JOSEPH MUSCARA - RES
J. PERENSKI - RES
PHIL REED - RES
ALAN REED - RES
ALAN RUBIN - RES
STUART D. RUBIN - RES
AMY SNYDER - RES

ALSO PRESENT: (cont.)

M. SRINIVASAN - RES
EUGENE TRAGER - RES
ROY TREPATH - RES
GOUTHAM BAGEHI - NRR
A.E. BANIONI - NRR
LARRY BURKHANT - NRR
ANDRE DROID - NRR
RICHARD ECKENRODE - NRR
EDWIN F. FOXIN - NRR
STEPHEN KOENICK - NRR
EILEEN McKENNA - NRR
UNDINE SHOOP - NRR
IAN HASTINGS - AECL Technologies Inc.
JOHN LEHNER - Brookhaven National Laboratory
LUCA ORIANI - Westinghouse

C-O-N-T-E-N-T-S

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

8:30 a.m.

CHAIRMAN KRESS: The meeting will now please come to order. This is a meeting of the ACRS Subcommittee on Future Plant Designs. I am Thomas Kress, Chairman of the Subcommittee. Other ACRS members in attendance are Mario Bonaca, Peter Ford, Graham Leitch, Victor Ransom, Stephen Rosen, John Sieber, and Graham Wallis.

For today's meeting, the Subcommittee will review and discuss with the NRC Staff the draft Advanced Reactor Research Plan and its implications on the NRC's regulatory framework. The Subcommittee will gather information, analyze relevant issues and facts, and formulate proposed positions and actions, as appropriate, for deliberation by the full Committee. Mr. Med El-Zeftawy is the cognizant ACRS Staff Engineer for this meeting.

The rules for participation in today's meeting have been announced as part of the notice of this meeting previously published in the Federal Register on June 20, 2002.

A transcript of this meeting is being kept, and the transcript will be made available as stated in the Federal Register Notice. It is requested that speakers identify themselves and speak with sufficient clarity and volume so that they can be readily heard.

That really means go to a microphone and use the microphone.

We have received no written comments or requests for time to make oral statements from members of the public. The only statement I have ahead of time is that, although we have a full day's meeting, I don't see how we can do justice to this substantial report in a full day, much less in the hour and a half that we have for the full Committee. But we will give it a go anyway.

Do any of the other members have any comments before we get started? Hearing none, I will call upon John Flack to get the meeting started.

MR. FLACK: Good morning. Thank you very much for giving us this morning on the Advanced Reactor Research Plan. My name is John Flack. I am the Branch Chief of the Regulatory Effectiveness and Human Factors Branch in the Office of Research. Although the title does not have Advanced Reactors in it, my Branch has the Advanced Reactor Group. Which has the lead on the non-Light Water Reactors. Which include the Pebble Bed and GT-MHR, innovative designs such as those.

What we plan to present to you this morning is more detail on the plan. We had previously been before the full Committee in April. And we went through the plan more at the higher level, visionary level you might say, presentation that was given at that meeting.

And today we would like to get more into the detail, the actual key elements of the plan, the issues and so on. So what I'll do is I will briefly go over the purposes of the meeting, our objectives, hopefully in line with your objectives, and discuss the key technical areas, four of them in more detail.

So I will turn it over after my opening remarks to Mary Drouin who will do the framework presentation. Stu Rubin who is part of the Advanced Reactor Group will do the Fuels presentation. Joe Muscara who is our point of contact on Advanced Reactors for Material Analysis. And then Don Carlson and Richard Lee will do the Reactor Systems Analysis.

I will then come back and talk about those other technical areas that are included in the plan. And then we will discuss a little bit more about the future plans and where we are headed.

As I have mentioned, the plan itself

focuses around key technical areas. And what we'd like to do is get down to the levels of the issues and areas and contacts where we are obtaining our information. We did take quite an aggressive approach, at least from my perspective. Had gone out and held workshops, meetings with various stake holders, including the ACRS, have traveled internationally to get as much information as we could or at least, if not at that point, identify where we can get the information.

And so, it is a rather comprehensive plan. We are hoping to get feedback, both at this meeting for the record on the transcripts, as well as would support a letter at some point and time. The earlier the better, certainly. That would really focus on two pieces.

The first piece is the plan itself. How we went about identifying our needs in the Office of Research or the Regulatory needs with respect to its infrastructure, expertise, tools, data that would be needed to take on these advanced designs as we see them. So that is really one piece of the message.

The other is to what level we need to continue to pursue and at what length of time the need for these non-Light Water Reactors. We are recognizing that we are in a state of flux in some ways. The Pebble Bed, as you know, has terminated its pursuit. And we are in a mode where we are just about phasing that out at this point and time.

But what the plan really says is that there are a number of needs that we have in developing the infrastructure. We have basically a Light Water Reactor infrastructure. And it took many years to develop that infrastructure. And what we see in the plan and all the different areas is that, it is quite challenging to take on a new design, new Light Water Reactor.

And to wait until the last minute for something like that would be catastrophic in the sense that the need to get the information in, to make the regulatory decisions that would need to be made in a realistic way, would certainly be compromised if we are not ready to do that at some point and time.

And so the second piece is a little bit more difficult to take on and that is, what is the vision that we see for the future for these non-Light Water Reactor plans. And when and how to go about developing an infrastructure that we would have in place when those designs do come in. So it is really those two pieces of the presentation or of the support we are seeking and the message that we are trying to get across.

MEMBER ROSEN: John, why are you stressing non-Light Water Reactor plans. I know there are Advanced Reactors that are Light Water Reactors, like the integral systems. Aren't there research issues involved there?

MR. FLACK: There are, but let me just go through the next view graph where it talks about the scope of the plan. What it is, is the scope of the plan itself focused on four reactor types basically, at this point and time. The Pebble Bed, the GT-MHR, the IRIS, and the Westinghouse AP-1000/600.

MEMBER WALLIS: John, some time in your write up that you sent us, the words "technology neutral" or something I think appears?

MR. FLACK: Yes.

MEMBER WALLIS: That would seem to cover anything, not just these. When we look at the specifics, we always seem to be talking about four examples.

MR. FLACK: That is true. There is really two aspects to the plan itself. One is the technology neutral aspect, which says these are the technical areas. These are the kinds of questions that we need to ask ourselves in each of these areas.

MEMBER WALLIS: For any reactor.

MR. FLACK: For any reactor. This plan goes further in saying well these are the four reactors right now that we have that will apply that thinking down to the next level.

So at some point, the technology neutral leads you to something more specific. You can only take it to a certain extent. The extent that we are taking it, again, we are asking ourselves three fundamental questions in putting this together. Why we need to do the research? What is the research that we need to do? And how do we plan to use the results.

And in each of the technical areas you can ask that against any design. In this case, we have these four designs basically on the table at the time that the plan was being developed. But to get to Steve's question, we see the greatest need in our infrastructure development in the first two.

And that is why you see a lot of the discussion centered around the High Temperature Gas Cool Reactors. It is a new technology. The staff is familiar with the Light Water technology. Not to say that there is not issues in the other two, IRIS and Westinghouse. And they are mentioned in the report, in the plan itself.

IRIS, for example, fuels and the new steam generator types. But IRIS is very conceptual at this point in time even. And it is hard to flesh out all the issues that are going to stem from that particular design. But we gave it as best a shot as we could.

Of course, AP-1000 is pretty far developed and we have a lot of infrastructure in place already to deal with Light Water Reactors. There are some issues in the AP-1000 that need to be looked at a little more carefully, like in-vessel retention and so on. They are called out in the plan.

But again, the plan is to try identify gaps, you know, the delta. The kind of things that we are going to need to put in place in order to do, to support the regulatory process at a later date. That is why you see when you get down to the technical level, a lot of the need is in the Gas Cool Reactor designs.

MEMBER FORD: Just to make sure I understand. The plan that was issued, the revision one, in June?

MR. FLACK: Yes.

MEMBER FORD: Focuses as you say on the top four. And you can take out Pebble Bed.

MR. FLACK: At this point.

MEMBER FORD: Yes, at this point. It states that it is technology neutral and that you are looking for big gaps in information? For next year's research work, what actually will be done?

MR. FLACK: Well, that is part of the budget process in setting, establishing priorities on what needs to be done. I mean, a lot of facets go into that process. That is part of the question that we are asking ourselves today, given the technology gaps in a non-Light Water Reactor field and with these other designs coming our way now, which I have listed below, and these are the ESBWR, SWR-1000 and the CANDU.

The question is, is how much, when to start and to allocate it in some way based on the priorities as we see them. Part of this meeting today is to try to find out from the Committee what their views are in establishing and feeding that in to setting those priorities.

So, I don't have the explicit answer to that question since it is evolving. But I think at some level, we need to develop our long term goals in a non-Light Water Reactor field, Gas Cooled technology at a certain pace. And as these other designs come in and as we see the needs for those designs which we'll be expanding the plan scope over the next few months to capture.

How those two work out together, we will know next year. But at this point in time, we are still trying to feel that out, understanding what needs we have and how much resources we have available.

CHAIRMAN KRESS: When you get ready to do the PIRTs, would they be individual PIRTs for each reactor type or would you envision an overall PIRT?

MR. FLACK: An umbrella PIRT.

CHAIRMAN KRESS: An umbrella PIRT of sorts.

MR. FLACK: Well, we are entertaining both ideas. We have had one PIRT already in the fuels area, very specific. And we'll have those in those fields where we see the issues and the need. The question on an overall PIRT where you lay out everything. I think there is two parts to that.

One is what you are hearing today, that is an infrastructure. Being able to ask the right kinds of questions at some level. And then there is the other piece of okay, now that we know the spectrum of issues, what is it that are more important than the others, and that becomes the umbrella PIRT.

We were thinking about having one umbrella PIRT. But we haven't decided when and what that would include at this point in time. But it is certainly an idea that's, I think, important.

CHAIRMAN KRESS: On the budget issue, will the budget you get drive the kind of research you get to do or based on the priorities. Or will you somehow take what you think the needs are and priorities and develop a budget from that and try to see if you can get that kind of budget? I'm not sure which way that goes?

MR. FLACK: Well we probably --

CHAIRMAN KRESS: Probably a little of both.

MR. ELTAWILA: This is Farouk Eltawila from research. I think the budget will drive the process, there is no doubt about it. There is limited amount of money. And the indication that we are getting from the Commission right now that we are going to pursue some activity in the Gas Reactor as well as Light Water Reactors. So, but there is a limited budget and the resources will be based on the devotion of the resource or split in the resources among the activity would be based on the seriousness of the application.

You know, because since we developed that plan as John indicated, we have three additional vendors indicated that they are interested in pre-application review of their design. So we will have to go through an add/check process based on the amount of information presented and the Commission support to address these issues.

I am going to add my two cents here about the issue of technology neutral. I think the issue of technology neutral is related to the regulatory framework. What will be 10 CFR.50, you know, that we are going to try to develop that as technology neutral. But when you come to the specifics, every design will have its own technical issue and we need to address these technical issues. So we are not developing a technology neutral, for example, thermal hydraulic for all these designs. Each one will have its own issues and a plan for resolution. But the technology neutral is related to the regulatory framework which Mary is going to address.

CHAIRMAN KRESS: Thank you, that makes a lot of sense.

MEMBER ROSEN: Let me make a few comments about the scope. First off, the IRIS concept is just one of a family of integral primary system reactors that is likely to come along. So highlighting it, I think is inappropriate. It is just the integral primary system reactors at this stage, that we should be looking at.

Furthermore, your list is, I think, a little incomplete, despite the fact that it is already a daunting list. It is a little incomplete in a number of respects. There are a series of very large pressurized water reactors being considered in Europe, the APR-1400. And the APR Plus, which is a very large 1700 megawatt reactor.

Also the EPR, which has enhanced active safety systems and extensive severe accident mitigation features. There is a high conversion BWR. Very large, could be as large as 1700 megawatts, but it could be smaller in the 300 megawatt range. And also there is a second generation Advanced Boiling Water Reactor being considered, very large 1700 megawatts.

So there just in the water family, there are a number of other designs that are going to need to be considered. Now I am not sure that they will each bring up different issues from the research point of view, but I don't think you have the full list yet on just the water side.

Now you do have a note on the bottom on the expected increase and scope of Generation IV. But I don't think it gives it justice and it needs to be given justice in this plan. Because of the extraordinary differences in design that the staff would have to deal with if Generation IV goes ahead as planned.

And let me just tick off for you what is in Generation IV right now, just so nobody in the Committee is surprised. It looks like Generation IV reactors, which are down the road a bit, but they should be in the plan as well. Will be a Gas Cooled Fast Reactor, a Molten Salt Reactor, the Sodium Reactors, both oxide and metal fuel, Lead or Lead Bismuth Cooled Cartridge Reactors, a Super Critical Water Cooled System, and a very High Temperature Gas System.

So Generation IV, both in its international near term deployment phase and in the longer term phase has got to put on the table an extraordinary range of new designs. And this slide doesn't do it justice, John.

MR. FLACK: Well, yes.

CHAIRMAN KRESS: The question I would

have, I think they are right in their priority being driven by how serious a particular application is. And I don't know how serious all these Gen IV's will be when it comes up to coming before NRC and saying we want to have this thing certified. I think they can't waste the resources on things that just have limited resources. We have to wait to see how serious the different concepts are.

MEMBER ROSEN: Of course, I am not suggesting that you waste your resources. What I am suggesting is that your plan have at least initially the full scope of things that are considered. And that it should be in the plan even if Gas Cooled Fast Reactor, let's say you just note that it is out there. You say no resources will be devoted to it at this time, if it goes forward, we will look at it.

But I think to say that we are going to look at the things we can see the tops of our heads over the hill in this plan is a mistake. Since we have the information that there are lots of other things potentially coming. The plan ought to acknowledge all of them. And say, here are the ones we are actually going to work on, even though we understand that there are major efforts both in this government, the U.S. government and in many, many foreign governments working collaboratively with the U.S. through the Generation IV International Forum.

There are many, many other efforts that are underway. I think a plan would be myopic and not as good as it could be. If it didn't take into account the full range, take into account Tom Kress' comment. Obviously you are not going to put money or resources into all of them. But you should at least acknowledge them and say they are out there.

MR. FLACK: That is a good comment.

MEMBER BONACA: As a minimum, I think for the framework portion which you want to have technology neutral, you want to make sure that by the time you are done, you can accommodate any one of these additional designs. And then when it comes down to the technology specifics, then you can ignore it because of the consideration right now in the short term that they may not be in the short horizon.

But I agree with the perspective that particularly when it comes down to the framework, we want to make sure it is technology neutral and accommodates anything else that will come.

MEMBER FORD: At your presentation to the Commission a couple of months ago I think it must have been on this subject. The question came up about the chicken and egg argument. When are the utilities and the OEMs going to come forward with serious applications for these various types of design.

And that feeds into your priority and planning to come up with some of the regulatory aspects. Are there any conversations ongoing with the OEM's and utilities more than just a letter saying hey we are coming with a pre-application? Is there any idea of their timing or their strength or will to go forward with this? Or are they just putting a case folder on the mat.

MR. FLACK: I don't know if anyone from NRR is present that wants to comment on that. The Office of Research had a lead on non-Light Water Reactor. So it is primarily Pebble Bed, to some extent IRIS and a GT-MHR. So we can really only speak for those.

I know there have been interactions, there's pre-application reviews that are being planned and discussed. But to what extent those interactions have been taking place with the specific applicants, I am not as aware of as somebody else might be. But I don't see anybody coming up. So I guess the answer is no. We are just kind of in a holding mode, looking at our infrastructure and issues that might evolve from these different designs.

But I think it is a good point that Steve made and that is we will put in sort of a list of the kinds of reactors that are out there and the status of them, recognizing that they are there. Whether they actually get developed and the materials and the fuels become, get to the point where they need to get to make the designs licensable, it may or may not happen.

But at least we know there are certain plants being considered somewhere in the world and having a list like that certainly and the status of that and staying somewhat engaged in understanding what is going on there is probably an important thing to do. So, yes, I think we can add a list to the plan to accommodate that.

MEMBER FORD: Tom, I know we are spending a lot of time on this graph, but it is central to everything we do from here on in. Is there any timing aspect? I noticed in your plan you say that the specifics are the responsibility of the licensee and the OEM. And that you are just going to set the higher level requirements.

And yet you have got a plan which is going on for several years, so does that mean for several years the OEM and the licensees will not know what they have to address in their specific applications. And that takes time, and therefore it could be 2020 before we even have one of these advanced reactors in place. Is that a ridiculous statement?

MR. FLACK: Well the plan is living. So it will accommodate, or attempt to accommodate whatever new technologies come forward or whatever plans come in as far as pre-application. Certainly when a pre-application review comes in already, we will be starting to focus hard on that because we are expecting something close. And that is pretty much the purpose of a pre-application review to be prepared for the design certification or whatever it would come in, in the short term.

So that is really going to drive a lot of it. But it is a living plan, so if there are needs and I think that by licensees and applicants looking at this plan and seeing the different research that we are focusing on, recognizing that we are not going to do it all. We are going to be relying a lot on them to do a lot of the work. They will have an understanding of what it is going to take.

So I think they can get that message even if the plant isn't specifically addressed by the plan. At some level there is some generic nature to the plan and the kinds of areas and issues and questions that need to be answered and asked in any case.

CHAIRMAN KRESS: Yes, let me give my opinion. The plan, as it sits has a lot of generic nature to it. In the sense that you outline things like the neutronic needs, the thermohydraulic needs, the fission product needs, the fuel needs. And you go right down the line. And then you went specific for the different reactor types.

But I think no matter what the reactor type is, those are the generic things you are going to look at. And so I think you have a good start even now, without spelling out these particular reactors, or where the research needs are going to lie.

MEMBER WALLIS: Is this a presentation of the plan or is this a presentation of the research needs?

CHAIRMAN KRESS: It is not a plan in the sense that it has schedules and milestones and budgets. They didn't intend for it to be that yet, it is too premature.

MEMBER WALLIS: That is why I have to ask. I think we are going to hear about needs rather than a plan.

CHAIRMAN KRESS: Yes, this is research

needs I think.

MR. FLACK: It's more of a process.

MEMBER LEITCH: It seems to me the plan divides very logically depending upon, as you have already indicated, whether we are ever going to build a Gas reactor. I guess certainly the regulatory aspects would be good to have technology neutral for that eventuality. But as far as the specific research related to gas reactors, I just have a lot skepticism about whether we are really going to build a gas reactor in this country in the foreseeable future.

You know, three months ago we were all spun up about the Pebble Bed Reactor. And it looked like it might actually happen. And now it is apparently not going to happen, at least in the United States. And I don't know what the status of the GT-MHR really is and how serious that really is.

As far as I know, there is no utility that has stepped forward and expressed any interest in that. Yet we had with the Pebble Bed reactor a utilities that looked like they were going to aggressively go forward. We were all spun up and spent a quite a bit of effort and now it is, we're not, apparently.

MR. ELTAWILA: I think this is the issue

that the whole Commission is struggling with right now. And we are getting you engaged in the struggle to share the pain. Because it is really true you know that how much resources you put and how much you delay the work.

You know, if we delay the work indefinitely, we will not be prepared for the industry. So we try to have an approach to be addressing the issue, remain engaged and try to do research. Because even if it is ten, twelve years from now, it is a long time. It appears to be a long time, but it might be a short time to develop the detail that you needed.

So we are going to remain engaged. As John indicated, there are other issues that we are better prepared for. For example, ESPWR, we have the knowledge. We can start the pre-application review and support the design in this case. ACR-700, although it is Light Water-Cooled Reactor, we still don't have enough knowledge.

So the Agency is going through the process of trying again to assess the seriousness of the application. And how much resources to put on some of these activities versus the others. But as Steve indicated, we are trying to remain engaged in all of these activities and we will try to allocate resources accordingly.

MEMBER BONACA: One question I have I would like to ask your perspective on this. It seems to me there has been the discussion, the presumption that you can have a technology independent framework. And then you can have you know, specific research for technology specific work in fuels and some of the materials.

Is it correct in all cases or is the framework somewhat influenced by the particular technology you -- can you make the separation? I am trying to struggle with that because, you know, for example for the Pebble Bed, we're seeing some new challenges that came, insofar as confinement versus containment, and to what degree those challenges affect the framework.

MS. DROUIN: When we get into my presentation, that is specifically one question that we are going to ask ourselves.

MR. FLACK: Okay, so we'll be there in a minute.

MEMBER BONACA: I was making the presumption in my mind and then I began to question the fact, you know, whether it was possible --

MS. DROUIN: And that is, you will see on the slide, is it possible to do that, or to what level do you have to put your --

CHAIRMAN KRESS: Well with respect to the Gas Cooler concepts, I agree with Ruth, I don't think the Pebble Bed concept has completely gone away. Just because Exelon pulled out. There are still some activity, it may not be a Pebble Bed. It may be another prismatic form like the Gas-Cooled Thermal.

So my view that is, and I think there has been serious thought given to certifying a GT-MHR. So, I don't think you put it aside. I think you have to have it on your agenda. And my only feeling was I would focus more on the GT-MHR than the PBMR right now.

MR. FLACK: Yes, that is a good point. I mean internationally, international interest in this gas cooled technology.

CHAIRMAN KRESS: Is high.

MR. FLACK: And in fact, my assistant is now in Russia with GA and others to see what is going on over there. So, and a lot will come out of that. I think a decision of where it is going to go.

Yes I think that it is important to continue to consider this as part of the mix of energy for the future in the United States.

MEMBER ROSEN: I think the other big issue that we may have skirted on, but not addressed, is what research given that you know the scope. What research should be done by industry and what should be done by the Agency. And that issue comes down to and I am stealing some of Tom's thunder here.

The definition as I understand it of what's a design basis accident. And what is a beyond design basis accident. Because, design basis accidents would be researched, I guess, by the industry and all of the supporting data for the design basis stuff would be done by the industry.

And whatever the staff felt it needed to do on beyond design basis would be paid for by the Agency and the government. Is that correct? And if that is correct, then isn't it crucial to know where the line is in terms of developing the plan?

MR. ELTAWILA: That is a very good question. But again, if you are thinking about the old way of doing business, but if you go into the risk informed regulation, there is no distinction between design basis envelope and beyond design basis. So you have to look at the whole spectrum. And with that, it is the responsibility of the vendor and the applicant to demonstrate the safety case of their plans.

So that is the complete responsibility. So any claim an applicant has, they have to provide the data and analysis to support that. On occasion, the staff will try to develop its own independent capabilities. Not in every area, in some of these areas, and again try to push the envelope, you know. That even though that our requirement of 10 CFR, for example, again, don't quote me on that in the future.

By let's say -- air ingress in IV gas cooled reactor is a very low likely event. But we know that it is very high consequence event. And by regulation, we might not require them to do anything, but the NRC might be interested in pursuing that issue further to be able to assess the margin and so on. So these are the areas that the staff will keep pushing harder to get its own independent capability in.

MEMBER SIEBER: I think once you get beyond the framework where you are developing the regulatory concepts, that it would be important for the agency to know what the vendors are doing. And the Agency research should be sort of complimentary to what the industry is doing.

And if they aren't doing any research, that means the concept is not ready to be born yet.

And so I would encourage pretty close looks at what the various vendors are doing and what is going on here in the U.S. and internationally. Which I think is what you are doing. You may not have the resources to do a good enough job.

MR. FLACK: But that's -- yes, in fact the pre-application reviews are very important in that regards of understanding just exactly where the applicant is going. And how much more do we need to understand as a regulatory agency.

MEMBER SIEBER: That is right.

MR. FLACK: So compliments, basically the work. Doesn't duplicate, but compliments. And to some extent there will always be this confirmatory piece to it.

CHAIRMAN KRESS: I think we better --

MR. FLACK: No other questions? I'll go to my next graph which is basically the structure of the plan. The different technical areas and basically there is nine key areas that we center on.

The first is the Framework and Mary is about to present that to you in some detail. Then there is the Accident Analysis which is the PRA, human factors, instrumentation and control. We kind of lumped it up under there. We followed the cornerstone approach in the plan. So it came along these various areas and I will touch upon that later this afternoon after the presentation on the Reactor Systems Analysis.

There is also the Fuels which is important. And you will hear from Stu Rubin on that following Mary's presentation. The Materials which covers the high temperature metals and graphite will follow. And then these others, Structural Analysis, I will touch upon. And Consequence Analysis I will touch upon at the conclusion of the presentations.

Eight and nine we will not discuss today at this point. We will be returning to the ACNW to discuss eight. And nine, we just are holding off at the moment. Nine is more of a place holder for work that we could possibly do to support other activities that are ongoing.

So, if there is no further questions, I'll turn the rest of the presentation over to Mary Drouin.

CHAIRMAN KRESS: I think that is a very nice lay out and a good way to present this information. And this was, where I was saying, the areas you are dealing with are technology neutral. Those apply to any reactor type. So it is a good way to organize things.

MEMBER FORD: This is just to make sure that I am not missing something. This is exactly the same as the framework that was issued back in May, I think it was?

MR. FLACK: With respect to the planning?

MEMBER FORD: Yes.

MR. FLACK: Yes, that is right.

MEMBER FORD: There is nothing new?

MR. FLACK: No, nothing new.

MEMBER LEITCH: John, just before we move on, could you give me an estimate of the level of effort that has been involved in bringing the plan to this stage?

MR. FLACK: That is difficult to say since a lot of it is more on the day to day activities of the individual staff members. We have discussed this with, for example, the user offices. There were working groups that were set up to interact, to talk about the issues. Of course, I have put a lot of my time into it over the last six months.

It is hard to say exactly, because there's so much of it, it is not like charged to one number and we can add it all up. But I think what is important about the plan, that isn't really written here, is that it is a communication tool. It has in fact opened up channels of communication across the office as well as with user offices.

The group in my branch is really the focal point, but we used the matrix organization. We really look to the technical expertise across the office. So we meet each week to talk about the plan, the activities going on. People get together and discuss this, as well as the user office.

So it is an excellent communication tool in just developing the plan and getting people on board and thinking about the future. Where are we going. What are the issues. What's the vision. And it does a lot in that regard. It is hard to put a number on all that.

MEMBER LEITCH: Yes, particularly this summarizing the research that is going on internationally, I think is particularly valuable.

MR. FLACK: Yes, another place.

MEMBER LEITCH: It's a good reference document, if nothing else really in that regard.

MR. FLACK: Good.

MEMBER ROSEN: I think there is another important thought here that needs to be said. And that is, really you are doing more than just trying to figure out where all the birds are. And where they are flying to and from. You are not just pure observers in this process.

Because by the decisions the Agency makes, it tends to build the future. It is more than just a monitoring role and getting ready for something that might show up. To the extent that you make decisions to go ahead and research things, you actually build the future. You are taking part in making the future. So these decisions should be considered in a lot more active sense than as just trying to catch up.

MR. FLACK: Good point. Okay, if there's no other questions and comments I will turn the rest of it over to Mary.

MS. DROUIN: My name is Mary Drouin with the Office of Research. I am here to try and give a presentation on where we are in terms of the framework. And you saw in the previous slide I had the word framework in quotes.

This means we have still not decided if framework is the appropriate word to be used here. But, for the sake of discussion, that is the word I am going to use. And how we plan to develop this for advanced reactors.

I am going to go a little bit into background. What we mean by the structure of this framework. What our plan is for developing it, our approach, some of the issues that are associated with it. And finally what is our status. Where we are and where we hope to be.

It is important to go a little bit on some background here, because we do have a current regulatory structure or framework that has been developed over the past 40 years. You know, that deal with the Light Water Reactor designs. And they certainly can be used through an exemption addition process by going through the current set of regulations and deciding where they are applicable and where there may be holes.

My personal feeling is I think that is a dangerous road to just strictly go down there, because you have a danger of overlooking something. Because you are going in with the mindset of something already on the paper. And when you deal with these new advanced reactor designs, you do have some unique operational design issues that need to be considered.

So while there again is applicability, it is there, but it is limited. Further, people can discuss the various levels that certainly risk insights have been brought into our current structure. But what we want to do here differently is from the very onset is bring our PRA results and insights and integrate them at a fundamental level into our decision-making process.

CHAIRMAN KRESS: When you say PRA insights, the only insights we have for PRA are for LWRs. That doesn't tell us very much about these other reactor concepts and designs. Do you mean the insights on how useful PRAs are and where they are useful. Is that the kind of insights you are talking about?

MS. DROUIN: I think it is both. And as you go through the process, you are going to have to determine what is the scope and level of detail that you want from these risk analyses into what kind of decision you are making.

I would argue that you could do right now, some limited PRA analysis. You certainly don't have your whole design, so your scope and your level of detail broadens and goes into more depth as you get more information.

But there are some assumptions you can make right now and it is iterative.

CHAIRMAN KRESS: Okay I agree with that. But I also gather from that that the framework is going to say PBMR concept -- will have a PRA. And it will be used in an iterative fashion. Can I assume that will be part of the framework somehow?

MS. DROUIN: Yes. I think also those insights will also feed into the framework itself. And we'll get into that particularly when we start talking about the quantitative aspects.

MEMBER BONACA: Because you're going to set criteria based on risk?

MS. DROUIN: That is right.

MEMBER BONACA: So we are forcing really, I mean if you set your criteria based on risk, you are forcing the use of PRA. You have to, to assess how a design would meet those criteria.

CHAIRMAN KRESS: This is interesting because this will be the first time that PRA actually seems to have been required by regulation.

MS. DROUIN: Correct. And part of the plan, one of the technical areas is development of the PRA. And you will see for that aspect there will be at certain times you are going to have to do research and that research is going to be dependent. And I am talking about PRA.

Your particular, it might be methods, it might be development of data. And that is going to depend, to what level are you depending on that analysis to help you in your decision making.

You're going to hear a little bit, at the full committee, on the risk-informed implementation plan about coherence, and we have an SRM from the Commission. Now this was for current reactors, you know that says, provide a plan for moving forward with risk-informed regulation to address regulatory structure convergence with our risk-informed processes.

So even though that is for the current reactors, and you talked a little bit this morning about technology neutral. If you talk about technology neutral that would also bring into your Light Water Reactors, our current generation of plants. And so ultimately, you know, we would like to have a single over-arching framework, a regulatory structure that encompasses both our current and our advanced reactor designs.

So at this point, in terms of our framework, and I want to really emphasize this next bullet because this is all the way through, we just started thinking. We haven't gone very far. Today is very timely. Because I certainly welcome, you know, input in our plan.

MEMBER BONACA: Just a comment I have.

You are really coming down to the structure of approach. Where you are saying criteria are going to be risk-informed and then you are talking about how you meet them.

Are you going to say something about safety goals?

MS. DROUIN: Yes.

MEMBER BONACA: Okay, so --

MS. DROUIN: I am going to get more into that. But I am saying, our whole plan here, you know -- and what I am looking for is that we are just in our conceptual stage -- is our plan and approach reasonable? Are we identifying the key issues?

CHAIRMAN KRESS: Will we still have design basis accidents that refine the licensing basis, you think?

MS. DROUIN: Good question.

MEMBER ROSEN: Well I would think from Farouk's comment the answer is no.

CHAIRMAN KRESS: I've been assuming the answer would be yes. But the design basis accidents would somehow recognize beyond design basis.

MR. ELTAWILA: There would be a design basis envelope. I think the distinction might be in the specification what the level of safety margin and all of the stuff. But for example, if you tried to have a design basis accident, I mention one issue here is the source term? If you try to have a mechanistic source term you have to go to beyond design basis to get that source term. There is no source term during --

So that is why I mean -- so you will require an applicant or licensee to do a test to try to verify what is the source term that is going to be used. So you might have to run beyond design basis tests, be required from applicant and licensee in order to address this issue.

Based on what Exelon presented, it is called a design basis envelope. It was not a design basis accident per se. And also, this is again all issues that need to be discussed during the next couple of years when Mary develops her plan.

I just want to make one point clear at this time. This framework does not, we don't need to have that framework to address issues like AP-1000, ESPWR. These are, can be licensed right now under the existing regulation without any problem.

CHAIRMAN KRESS: And they probably will be.

MR. ELTAWILA: And they will, definitely.

MEMBER SIEBER: It would seem to me though the concept of design basis in quality requirements came about because in the early days there was not the computational PRA that defined what the risks were. And so this design basis was sort of a substitute for that. And as we move along and progress in the PRA technology, we come up with the concept of maybe some design basis quality requirements are too much or too little.

And that is the basis of the South Texas amendment. And it would seem to me that you ought to start with a clean piece of paper and decide whether you need the old style design basis, or not, or have PRA and safety goals define what the quality requirements are and what system requirements are, whether you need a containment or not and so forth.

And in this framework, that is where you would decide how you are going to apply that. That would define what the new rules look like, to me. That is one way, anyway.

MEMBER ROSEN: In effect, provide a graded approach to quality.

MEMBER SIEBER: That's right.

MEMBER ROSEN: Which by the way is not new. We never really did it, because we didn't have the tools. We had black and white. Our grading was black and white, yes or no, on or off. Now we can do much better.

MEMBER BONACA: You still have to design the ACCS System if you have the water reactor design. So still you'll have to define what are the criteria that you have to fulfill with the ACCS System. So you have to come down I think to some kind of design basis event, whatever.

CHAIRMAN KRESS: I think I agree with that. It is a very nice tool for the designer to design to. It could be risk-informed. It is also a good way to work in your concepts of defense in depth --

MEMBER BONACA: Well, I think information should reduce the burden, the unnecessary burden. That's the whole purpose of that. But in reality, ultimately the designer has to know how much water they have to provide, under what conditions and where.

CHAIRMAN KRESS: I think one of the real challenges for getting design basis accidents is going to be what are your figures of merit that you have to meet.

MEMBER SIEBER: That's right.

CHAIRMAN KRESS: For some of the concepts, you just got to have new figures of merit. You can't use the ones you have been using for LWRs.

MEMBER BONACA: True.

CHAIRMAN KRESS: I think preserving a design basis concept is probably worthwhile thinking about.

MS. DROUIN: When we look, forgive my typing there at the top. When we look at this structure and this framework, a lot of basic questions when we just start dealing with it conceptually. Where you would start putting the words to it.

But, you know, one of the basic questions that comes up first. Can it be established at various levels? Should it be established at various levels? I mean beginning at the top, should it be a generic level where it is applicable to all currently envisioned designs? Or should it be more design-specific?

And so we have multiple frameworks, one applicable to each design, or some combination of the above. Our approach right now is going to start with the Generic I High Level, or conceptually it should be technology neutral. And then as you go down in depth, but again, is this the right, you know, approach to go after?

Also another fundamental question is, should the framework have both qualitative and quantitative aspects to it, criteria?

CHAIRMAN KRESS: Well you know how this committee feels about that. The "n". We want that "n" in there. Quantitative. I think once again, you are establishing various levels depending on whether you are trying to preserve some sort of Appendix A, general design criteria.

MS. DROUIN: Yes.

CHAIRMAN KRESS: That is where it is going to get tricky.

MS. DROUIN: There is going to be difficulties and issues. Both policy and technical associated as we look at these and try and make some decisions. We kind of jumped ahead a little bit a few minutes ago, but major point.

We said that the risk insights, our PRAs are going to be an integral part from the very beginning, such that as each reactor is licensed. You are going to bring, your risk insights will be used as appropriate, you know, at each step of the process in your decision making.

And because it is going to be integral, we want the structure, this framework to be risk-informed and to be used as a key player and help focusing the regulations and where the high risk areas are. And because it is also still going to be risk-informed as with our current, and we are going to maintain the principles, you know, of defense in depth and safety margins.

And all of these have issues that are going to be associated with them. That I will touch on briefly as we go along.

MEMBER WALLIS: I don't know how you do that? How do you write these new regulations for something that doesn't exist yet, based on high risk areas when you don't have a PRA yet. You don't know what the high risk areas are?

MS. DROUIN: That is why it is iterative.

MEMBER WALLIS: Well you need a better way of designing something. Then something which is so dependent on waiting for something else to happen.

MS. DROUIN: I think you have a lot of experience. And when you talk about something that is going to be technology neutral, the issues that you are talking about can be at the next level. And what I mean by that is one approach is you write your regulations at a high level where they are technology neutral.

And then as you come to the next level, perhaps in your regulatory guide, then you start dealing with the specific issues on the specific reactor designs.

MEMBER FORD: Maybe it would help us, Mary if you, could just give us an example? I am mirroring Graham's concern, how do you apply such a -- Well, what is the frequency of an event. What is the impact going through a PRA analysis which is technology neutral. Could you give an example?

MEMBER BONACA: You could use option three as an example. Because there you have, for example, defense in depth with prevention and mitigation that you set with certain criteria. You could talk about how do you allow in this framework. Maybe, there's a portion that could take place in different ways.

MS. DROUIN: Well, I think also we are stepping way ahead than where we are even in our thinking process at this point. What we are trying to do right now is to outline an approach and a plan for getting there.

How it is all going to fall out, it is too early to say at this point. I do think that you can come in and you have enough knowledge at a high level of these reactor designs to build a high level PRA that will kind of focus you -- You know, I am not trying to get to this valve or this component, is what you have to worry about.

MEMBER FORD: Okay.

MS. DROUIN: You're not there at this point. You are at a much higher area, level. Sorry. And maybe LOCAs, I am just talking about now, conceptually. Maybe LOCAs is where you need to worry about versus maybe it is more transient. Or maybe it is some other different reactor type. But I think you do know enough about the designs to come in to help you formulate, for example, what your design basis accidents should be.

MR. ELTAWILA: I am going to go out on a limb for right now and say it is not going to look anything different from what we might -- it might slightly look different from what we have right now. But instead of having embedded in the regulation a pellet temperature and correlation for maker and just for oxidation model. You are going to make the regulation neutral.

For example say that you should not have a fuel failure for example. And it is almost written exactly like that right now. And relegate all the details about the evaluation model. About how to demonstrate that for the difference type of reactors into the regard. So that, I really, we are making it bigger than what it is. But it is going to look -- just to clean up the regulation to make it look at very high level and the rest of this stuff will be in a specific other document.

CHAIRMAN KRESS: We are not thinking exclusively of the CDF and LERF.

MS. DROUIN: And you will see that in another slide.

MEMBER WALLIS: I think it would help if we had a framework for the current regulations. If we really knew what that was, then we could perhaps duplicate it.

MS. DROUIN: And I'm going to get into that because our intent is not to re-invent, you know a lot of good work that has gone in the past. Take advantage of all the previous work. Such as the framework that we have developed for risk-informing Part 50.

CHAIRMAN KRESS: Let me ask you about that. You know when I think about that framework, I picture this table where you have various frequency events and then you have a CDF and a conditional containment failure probability for those which are acceptable levels.

That bothers me, if that is what you mean as the starting framework.

MS. DROUIN: I am going to get into that.

CHAIRMAN KRESS: Okay, but that bothers me if that is your starting framework. Because those concepts may or may not be the right ones.

MS. DROUIN: That is exactly right.

MEMBER BONACA: Although from the perspective of the way they structure the table, prevention and mitigation?

CHAIRMAN KRESS: That may even be wrong.

MEMBER BONACA: Yes, but I am saying that you could introduce flexibility in that. And how to achieve that in a way that, and I am not thinking of the Pebble Bed. I mean, where you can be able to accommodate a balance as long as you can achieve the ultimate objective which you are setting. So there are ways in which you can do flexibility with that.

CHAIRMAN KRESS: That is what I'm working toward.

MS. DROUIN: Let me skip the next slide. I am going to come back to it. But I think it would be easier if I go to the next one, slide nine. Because I wanted to go through our current framework that we're using on Part 50. And this is the start of the framework.

And that it has, our framework, our current framework that we are using on Part 50 has both qualitative and quantitative aspects. So it is not just that single figure that you are referring to that has numbers.

On the qualitative aspect we say there is two parts to it. We have one that's a hierarchal structure that starts with the goal to protect the public health and safety. That is the over-arching structure.

CHAIRMAN KRESS: Do you have a definition of what that means?

MS. DROUIN: I am going to get to that in the next slide. It starts with that goal. And then the second part of the qualitative is that it is going to be constructed in such a manner that it maintains a defense in depth philosophy. You will see that hopefully on the next couple of slides.

And then the second aspect is the quantitative part of the framework. And that is where we bring in quantitative guidelines to help us define what is meant by safe enough. And we do that with the current one by using the safety goals.

If you go to the next slide, again dealing with our current. Looking at the qualitative aspects now what we mean by the hierarchical structure. And what we are saying is that with the advanced reactors we are going to follow this same concept.

That we are going to start with this goal of protecting the public health and safety. It is going to be the top-down approach. And then how we define what that goal is, or differently, how we are going to achieve it, is identifying the cornerstones. And the cornerstones on the current framework were derived from the reactor oversight program.

And there were seven cornerstones, but we focused the cornerstones for Safe Nuclear Power Plant Operations. And you will see on the next slide that we had focused in on the reactor safety ones.

And we are going to implement those cornerstones through strategies of accident prevention and accident mitigation. And then ultimately to achieve those strategies, we are going to employ these tactics such as defense in depth, safety margins, design bases. We are going to use those to help us form the regulations and how we do oversight.

So that is the hierarchical structure of the current one and we are going to stay with that same concept. We see no reason to change it right now for the advanced reactors at that level.

On the next slide, and you will see there over to the left, the top down going from your goal to your cornerstones to your strategies to your tactics.

Is that on the corner framework, those are now defined to the next level of detail. And so if you start with your reactor safety, there were four very specific cornerstones that were identified for the reactor safety.

Your Initiating events, mitigation systems, barrier integrity and emergency preparedness. Now whether or not these will be the same. And whether we should expand, for example, over to radiation safety and security, these are all questions now that we are going to have to deal with and answer for the advanced reactors.

And the same thing when we get to the strategies. Here for the current reactors under accident prevention we said limit the initiating events, limit your core damage frequency given you have the initiating, limit your radionuclide release and limit your public health.

Whether those remain the same at that level, the same strategies, are questions that we are going to look at and answer.

CHAIRMAN KRESS: Remind me what you meant by radiation safety, the bullet called general public. Was that intended to apply to smaller releases of radioactivity? Or control of waste? Or what was that bullet for? I forgot.

MS. DROUIN: You know, to be honest, I don't remember. I would have to go back and look at the definition of that one.

CHAIRMAN KRESS: What I am trying to decide is whether or not under reactor safety you just focus on things like prong fatalities and latent fatalities. And relegate things like frequency of small releases and things of that nature to the radiation safety.

MEMBER SIEBER: I think there is two different things there. For example, if you look at the oversight program, it talks about routine releases ODCM and those kinds of things. But if you look at it from a public safety standpoint, it would have more to do with the effectiveness of evacuation plans and warning systems and potassium iodide. At least in my way of looking at it.

So, it ends up in the global sense as a combination of the two. It is either chronic or acute. And we need to limit both effects, both the chronic effect and the acute effect.

MEMBER WALLIS: Why would anything change on a new design from this framework?

MS. DROUIN: I think when you talk about at this level, the concept, the structure I don't think changes.

MEMBER SIEBER: Right.

MS. DROUIN: I think at the level of protecting the public health, reactor safety, radiation safety, security, I don't think that changes.

Accident prevention/mitigation I don't think changes. But how you define those cornerstones and how you define the strategies, that next level may change. I don't necessarily think that your tactics will change. But how you define the tactics may change.

MEMBER BONACA: Wouldn't that be very much PRA-driven. I mean how you apply defense in depth and safety margin. Although they are, we always say that PRA is subsidiary to the defense in depth. Yet you are using the PRA to make decisions about how -- the way you are going to apply it. So that is going to take you in different directions.

But insofar as the prevention and mitigation right now, you are very, in Option Three you are very prescriptive about how you go insofar as what, how much you give to prevention, how much to mitigation. Any thoughts about how far you are going to be in allowing a shift, for example, between the two? Some new designs are challenging in that particular area.

MS. DROUIN: We have not gotten there yet.

MR. FLACK: Yes, I think that is a good point. I think a lot is going to depend on how much we really know about the plant. That is where I research, I think becomes very important. Because the more confidence and the more data and the more information you have about a plan, the better decisions could be made.

Because the lapse in that is going to result in the need for more defense in depth and so on. So I think that is going to play out in kind of a --

MEMBER BONACA: The reason why I asked that question is it seems to me that in the Pebble Bed, I mean there was the challenging issue that how far are you going to allow to prevention insofar as -- and then, less, okay.

So that is really what you are going to do with those issues at that strategy level.

MEMBER SIEBER: I guess another factor in new advanced designs is that there is going to be more uncertainty than you would have with a fleet of 25 year old PWRs.

MR. FLACK: That's right.

MEMBER SIEBER: Because of that, you are going to end up initially with more defense in depth and you may ultimately accept that as being adequate.

MEMBER BONACA: That is a very good point that Jack is raising. Because so much of what we call regulatory burden today, wasn't driven by purely, simply we just slap on a requirement. It was driven by uncertainty that was inherent in the technology 30 to 40 years ago.

So the risk is that, although we want to have all the necessary and sufficient criteria here, we are going to have burden.

MR. FLACK: I don't know how we deal with that. Initially we'll have to.

MS. DROUIN: AS you can see, our approach is to go through each level here. And you know, evaluate its applicability and its appropriateness for advanced reactors. So each one is that safety goal the appropriate one. You know the current framework uses the QHOs. Are those the right ones to be used here? In defining how you are going to protect the public health and safety. Are the cornerstones appropriate? Do you need to expand it? Same thing with the strategies, both from a qualitative perspective and from a quantitative perspective.

And again, have we identified the appropriate tactics? The level of detail that we are going to go into, is that appropriate? I'm going to discuss these a little bit more on the next couple of slides where I have given some examples. It is hard sometimes to separate out policy versus technical because sometimes they feed into each other in trying to answer the policy. You might have to have more technical understanding.

And I haven't tried to list everything here, just some of the preliminary ones that we have identified and thought about. Again, I have said this one several times, should additional cornerstones, just at the high level, should we go beyond the reactor safety? Should we include radiation safety, security and safeguards? And then within the reactor safety are the four that are identified there, the appropriate ones. Should we start looking into land contamination, for example?

CHAIRMAN KRESS: You know, I don't even think you should have even asked the question. To me it was obvious, yes you should be thinking about it. It is part of your regulatory objectives to have an acceptable level of insult. And that is an insult that you have to think about. You know, we would say sure.

MS. DROUIN: Okay.

MEMBER SIEBER: Yes, but it is not in the policy now.

MR. ELTAWILA: It is a policy issue.

CHAIRMAN KRESS: There are things -- but it is dealt with in the regulations to some extent.

MEMBER ROSEN: You are not implying that all of these are new questions. I think, should the level of safety be raised for new plants, your next bullet. I thought the commission has already expressed its expectation on that subject.

CHAIRMAN KRESS: Well that was sort of ambiguous statement.

MS. DROUIN: Yes.

MEMBER SIEBER: That's right and it needs to develop into some kind of policy.

MS. DROUIN: And what it is meant by that.

MEMBER SIEBER: Right.

MEMBER ROSEN: It's not going to be less safe than the current generation.

MS. DROUIN: It will not --

CHAIRMAN KRESS: It certainly says that.

MEMBER FORD: Mary, where does early site permits come into this whole argument?

MS. DROUIN: I'm sorry?

MEMBER FORD: Where does early site permits come into this whole argument? I keep thinking about timing. We have got three applications for early site permits on the desk right now. And as I understand it from what I have seen, it may require a fair amount of additional work.

I don't know if there is any research money being allocated to it. Where does it come in on this policy issue? Is there any policy issues associated with early site permits for unspecified new reactors at those three sites?

MS. DROUIN: I don't have an answer to that.

MR. FLACK: Yes, I am not aware of any at the moment. We are actually testing the process as we go. As you know, this has not been exercised before. And a lot of the interest is in seeing how this will go.

But at the moment, there wasn't anything within the context of the plan itself that research needs in that area at the moment. Whether or not something else comes up related to the framework. Actually that may come out of this process as it is being exercised.

MEMBER FORD: So, for any one of these three sites that are being proposed, if someone came in and said we want to put in an MHR, a GT-MHR, the existing regulations would just be sufficient?

MR. FLACK: Well it would be applied.

MS. DROUIN: Yes, you wouldn't say that the existing regulations would be sufficient, but you would use the existing regulations to make your decision. And you would go through them to decide which ones were appropriate and which ones would not be appropriate. And where you may need to make some changes to the current ones to meet that reactor design.

MEMBER FORD: Okay.

MS. DROUIN: And then we get to --

CHAIRMAN KRESS: Your regulations ought to be site-related. Talking about the various site permits. When you are talking about a LERF, that is a site characteristic. That is not a plant characteristic.

MS. DROUIN: That's site.

CHAIRMAN KRESS: The LERF is a plant characteristic, the acceptable value of LERF is a site characteristic. When you are dealing with regulations you are talking about acceptable values. So, implicitly, you have to have a site in mind. And that ought to be part of the thinking when you deal with early site permits.

You have to ask how many plants are already on there? What is their collective LERF value? And am I going to put a new one on there? How much I am going to add to that LERF? That's the sort of thing you have to think about.

MEMBER FORD: I am really showing my ignorance here at this point. As soon as the different radionuclide release, which give rise to different pump fatality statistics. Would that not impact on ESP?

CHAIRMAN KRESS: Absolutely it would. If you got a different mix of isotopes for example, and different quantity of isotopes, then the definition we now have for LERF, acceptable value of LERF in terms of what it means in terms of a surrogate for prong fatality safety though, just completely wrong.

MEMBER FORD: So, that is dependent on that --

CHAIRMAN KRESS: Absolutely. On the type and the site.

MS. DROUIN: One of the reasons that when you look at the hierarchical structure of the framework and if you stay at the highest level where you are coming down you have your goal, your cornerstone, your strategies and tactics. And while conceptually, you know, I do firmly believe that that is applicable to all technologies.

The details of it that are currently there for Part 50 are there because of how you are using that framework. And that framework was being used to help look at the current set of regulations and see if they need to be revised, deleted, enhanced or whatever.

So now we are going to stay with that same concept, but how this framework is going to be used, is a critical decision in this whole process. When and how it is to be used, will be fundamental in helping you decide in determining whether at each part whether your goals, cornerstones, etc. are applicable and appropriate.

So, one of the very fundamental questions that has to be asked is how do you plan to use this? When are you going to use it? And how are you going to use it?

CHAIRMAN KRESS: I think you are going to have to back up on this LERF concept. Because it is going to be site-specific. It is going to depend on the design of your reactor. What type of reactor you have. I think you are going to have to back up to the next level again and say my goals are something else. They're prong fatalities. They're land contamination, whatever. They're frequency of release of fission products.

I think you are going to have to define the high level acceptance criteria in that. And whether you can back down to a LERF, is in my mind, questionable at this time.

MS. DROUIN: I didn't put it on the slide, but it is in my notes here. I mean I still haven't given you your quantitative health objections. Are those even the appropriate ones?

CHAIRMAN KRESS: That is questionable too in my mind, yes.

MS. DROUIN: You have to start there.

CHAIRMAN KRESS: That is a good place to

start.

MS. DROUIN: That is where you have to start. What should be that safety goal?

CHAIRMAN KRESS: Yes.

MS. DROUIN: And the safety goal that we are using right now in the current structure are the QHOs.

CHAIRMAN KRESS: Well, I think that is a good start.

MS. DROUIN: You know, should we start there and then given that, what are the appropriate surrogates? Right now we are using CDF and LERF. Are those the appropriate ones? And then given, once you determine what are your appropriate surrogates, whether they are CDF or LERF, then what are the appropriate quantitative guidelines associated with them?

CHAIRMAN KRESS: LERF may be appropriate, but the one that's in regulatory guide 1.174, I don't think is appropriate. 1 time seven minus five per year, I think you should throw that one out of your mind and start from there.

MR. CARLSON: Could I make a comment on that?

MS. DROUIN: I think you have to look at

both what it should be just qualitative, what should the surrogate be. And then what should be its quantitative value.

MEMBER SIEBER: I think that problem is pretty complicated because the source term changes with burn up, number one.

CHAIRMAN KRESS: That's right. That 1.1 times 10, to the minus 5 depends on it.

MEMBER SIEBER: That's right. And so really what you are looking at is how much uncertainty is there in defining what LERF means in terms of QHOs. And then you have to make another decision beyond that, which is how conservative do you want to be.

You may end up with LERF times some factor that you agree on envelopes the uncertainty. You know that is one way to do it. Otherwise, a computation of that gets very complicated. As you and I know.

CHAIRMAN KRESS: Yes. We have hashed that one out, haven't we.

MEMBER SIEBER: Took a long time.

MS. DROUIN: I also think another very tough one is going to be you know, the level of defense in depth and what we mean by that. Right now, under the current framework, let me say it a little differently.

I think your thought process is different when you are looking at a current set of regulations and you are risk informing them and you want to maintain the defense in depth that is built into them versus starting fresh. Where you want to build defense in depth, but you don't want to go to the extent where you are now creating undue burden from the very beginning.

So how you define defense in depth from that perspective, and safety margins so you don't go too far. I think brings different questions that need to be asked further than what we were doing on the current Part 50.

CHAIRMAN KRESS: Yes, we'll be very interested in how you come down on that eventually.

MS. DROUIN: I will be too.

MEMBER WALLIS: Well I suspect you'll find what Jack Sieber was saying. That if you go to something which you don't know much about, you are going to have to have more defense in depth to account for your uncertainty about what is going to happen. So it is not going to be a question of reducing burden.

You're going to reduce burden maybe after you have had some experience with these.

MS. DROUIN: That might have to be the way it gets. Going back to the previous slide.

MEMBER SIEBER: That's not progress.

MS. DROUIN: Yes, we want to create -- and I apologize the slide did not get changed. It is supposed to read outline a path for generating a framework. Decision-making criteria was supposed to be framework there.

You know, how do we intend to create this framework. You know, recognizing that you know, we want a framework that is going to ensure that the design and operating requirements for advanced reactors are developing in a consistent, systematic and structured manner.

I think that is very important. We want to make sure that the advanced reactor regulations, you know, are going to be directly tied to these high level safety goals and principles that we end up defining. We want to be able to show that these safety goals, however we define them, are met. Perhaps even exceeded. And that is another issue we are going to have to deal with. And ensure that the regulations, where appropriate, are performance based.

MEMBER WALLIS: So this is, again, a statement of objectives?

MS. DROUIN: Yes.

MEMBER WALLIS: There isn't much of a plan?

MS. DROUIN: We don't have a plan yet.

MEMBER WALLIS: You call it a plan, though.

MS. DROUIN: Well this is what we want our plan to do.

MEMBER WALLIS: Right, so while I am sitting here assessing the likelihood that you will ever succeed. And all you keep doing is asking questions and having objectives, and I don't know how to assess the probability that you will ever get there.

MS. DROUIN: Well I think we are going to have to come back. Because again, I wanted to put right up front here, we just started on this.

MEMBER WALLIS: You have talked to us before, so can't have just started.

MS. DROUIN: This is my first time up here.

MR. ELTAWILA: I came here, Graham you are correct, and talked about it. But again, we go through a budget process and we will try to allocate resources and all this stuff. So it is just part of the --

MEMBER WALLIS: That's the impression I get. Is that when you get the money then you will figure out what to do.

MR. ELTAWILA: That is not fair, but at --

MEMBER WALLIS: No it's realistic.

MR. ELTAWILA: I suggest you don't give credit to the staff at all --

MEMBER FORD: Jack, at the very beginning in your opening statements, you correctly said that this plan is identifying all of the issues that have to be addressed, from a framework regulatory position and the technical position. You then said the next stage would be, with our help, to come up with some sort of PERT. To prioritize all of those questions and then go and do something. When will the PERT be done?

MR. FLACK: Well, we talked about the umbrella PERT. PERTs are going on as we speak within the technical areas themselves. What are the issues and ranking those within, just for example, fuels.

Across the board again, it gets back to this question of what is it that is causing us to react now, versus what do we need to put in place for the long term and maintain that for the future, someday at a gas cooled design coming in. I mean there's two pieces to that.

The first piece is that we are reacting to pre-applications. Design certifications that are very close on the horizon that we'll need to prepare for. What are the issues? Since these are light water issues, we are more prepared to deal with those kinds of issues.

The question on how much to put into the longer term goals of establishing an infrastructure, a regulatory infrastructure that can process an advanced gas cooled design. I think that is the question. And how this trades off. Whether or not a global PERT will come to an answer on that question, I don't think so.

I think that is more of a PERT that needs the commission itself to decide where we go and set that vision. And from there and allocating what needs to be done, how much resources are to be spent in each part of this. Well then we have a plan next to say, well these are the things that are coming out to be the most important things. They are going to need a long term effort that we need to start now if we want to be prepared when the design comes in.

A lot of this plan focuses on that.

Getting the tough issues on the table. Saying are we really prepared to deal with these. And if not, when would we be needed to deal with these and try to establish some time frame and resource level to accommodate that. There is no simple process that can get us an answer. I mean everybody has their own views on this.

A lot of it will be driven by the Commission's desire to establish certain things and goals for themselves that will then be implemented by the staff. So I don't think that kind of PERT.

The PERT that we mentioned earlier, umbrella PERT. Would be okay, now, for a non-light water reactor gas cooled designs, what are the key issues. And we see that even coming as we speak from the plan itself. That is why we are going to be focusing on three of them. Basically the materials, the fuels, and the reactor system analysis.

MEMBER FORD: For gas cool reactors?

MR. FLACK: For gas cooled reactors. I mean these are the most complex issues that we are dealing with. There is a lot to them. There is a need to have people familiar with those areas that, in gaps we see more. And so, I think it is coming out at that level from laying everything out on the table, what is it that needs to be addressed in the long term that we need to start doing now. And a lot of that is from our interactions with stakeholders and the Commission.

MEMBER FORD: Are there sufficient plans, i.e., actions ongoing to address evolutionary Light Water Reactors? The ones that you, some of them that you have mentioned, which are probably much more likely to be built than a gas cooled reactor?

MR. FLACK: Well we are expanding that as we speak actually.

MR. ELTAWILA: Can I add something to what John is saying here. So Graham does not think that we are not working on any of these issues. Just for your information, for a year right now we have been modifying our thermohydraulic and severe accident core to deal with gas cooled reactor. We have been negotiating with DOE about cooperative agreement on performance testing.

But to answer Peter's question directly for advanced revolutionary light water reactor, we are right now in the process for that. That is part of the complication of the issue.

The money that was going to be spent on testing of Pebble Bed fuel, right now is going to be reprogrammed to address ESBWR issue. So we are going to delay decision about testing on gas cooled reactor. For other reason, you know that DOE is not ready. We don't have the Pebble yet. And we have the money, so we move the money to address ESBWR.

So the priority in my opinion is going to be AP-1000 which we are definitely are on top of everything. And I don't think we have any problem with the ESBWR and the ACR-700, that is the Canadian CANDU reactor.

But we will continue to work on gas cooled reactor and when we see opportunity to enter into cooperative agreement that is going to be cost effective for the government, and within our budget, we will enter into this agreement to get information from overseas.

So, the plan is being implemented in certain areas. In case of Mary, the Commission told us not to work on the framework in `02. So that was the Commission decision, so we cannot go against the Commission directions.

MEMBER FORD: You said the framework --

MEMBER SIEBER: Just once --

MEMBER FORD: You don't need to change --

MR. ELTAWILA: We don't need to change the framework for light water reactor, they are certified under --

MEMBER BONACA: I have a question that. I received in the mail, and haven't been able to review it all, but the document from NEI. I believe NEI 02-02.

MS. DROUIN: Right.

MEMBER BONACA: Where they are proposing you know, using cornerstone so that the framework. And there is a full approach that's being described there from the reactors. You are communicating with each other?

MS. DROUIN: Yes, we've had a meeting on that and we're going to continue to have meetings with them. And that is going to be one of the inputs here that we are going to take into account.

MEMBER BONACA: Okay.

MS. DROUIN: Absolutely. We have already started looking at it.

MEMBER BONACA: Is that the final document from NEI or is it a proposed document for comment or?

MS. DROUIN: No it is just --

MR. ELTAWILA: It's send as an information paper for NRC. They are not asking a formal reply from NRC. And the staff is going to take that into account in developing the framework and in the coherent.

MEMBER BONACA: Okay, so really the staff in this communication with stakeholders.

MR. ELTAWILA: That is correct.

MEMBER FORD: Can I ask a question of Tom and yourself. There is another plan? On action plan, ongoing for evolutionary light water reactor.

MR. ELTAWILA: in the ESWBR, yes.

MEMBER FORD: Those are ongoing plans. I am thinking more selfishly the research report aspect. Would it be useful that you were briefed on those plans, the evolutionary light water reactor?

CHAIRMAN KRESS: I certainly think so.

MEMBER FORD: Because the way I am seeing it is that the plans that you are talking about for gas cool reactors. By the time we are ready write a research report, are not going to be - We could say yes you hit all the right questions, but the result of those questions is not going to be identified.

MS. DROUIN: When I talk about plan here, I am talking about my piece which is the framework.

MEMBER FORD: Yes, I understand that.

MEMBER SIEBER: It would seem to me though when you consider just the elements that you are dealing with so far. You have on the one hand phenomena logical research. Which is how the systems work. How the fuel responds. And even going so far as to try and figure out what the source term is for difference between a fast reactor and a thermal reactor and fuel matrix.

Then you have on the other hand, this framework. And think the framework has to come first. I believe that there are some flaws in the current framework to be corrected. For example, the concept of LERF being a site issue. The fact that land contamination isn't in there.

And LERF may not be the right surrogate. So I think that you have to do that first before you have an idea as to how you want to structure regulations to license and advanced plans. Then on the other hand you need to know about the phenomenon, the responsive materials and the behavior systems in order to actually be able to put your arms around the specific reactor types.

So I see it as two different things. And I see the framework as probably having a greater conceptual priority than all the other stuff.

CHAIRMAN KRESS: Yeah, I guess I would disagree a little with that. I think parts of the research plan that deal with the things like neutronics and fission product release and materials. I think no, you are going to need those.

MS. DROUIN: Yes.

CHAIRMAN KRESS: Regardless of what regulatory structure you don't have. So I think they are independent. There are some things in the plan I think that will depend on what kind of framework you could have. And that has to do with what kind of PRA research you will need to do. And some things having to do with that sort of thing. To me in my mind, they are almost independent.

MR. FLACK: Yes.

MEMBER SIEBER: That's my point.

MS. DROUIN: I think there is some that are independent, but I would also say that there is some cases where you are going to need some research to answer some questions to resolve some framework.

CHAIRMAN KRESS: Yeah, I think going in that direction is definitely a positive truth.

MEMBER SIEBER: That's what ought to be identified right up front.

MS. DROUIN: And those are all the thinking things that we are going to try. In September we aren't going to have answers. But hopefully we will have identify and how the approach we are going to use.

MEMBER BONACA: So this is preliminary plan or preliminary framework? What is going to be in September.

MS. DROUIN: No, what you are going to see in September is the preliminary plan.

MEMBER ROSEN: That is our next meeting.

MEMBER FORD: The itemization of things that have to be done, will not be done I understand for Fiscal Year 2003. Sometime or other beyond 2003 to attack those actions that you are going to identify in September.

MR. ELTAWILA: Mary, can I say quick words from your mouth?

MS. DROUIN: Please.

MR. ELTAWILA: The plan that you are talking about here, so we won't start from a clean sheet of paper to develop this regulation. Which is going to build on the existing framework of 10 CFR that we are using right now to change the information 10 CFR 5046 to 4044. And you are going to look at that framework to see how it can be expanded to include advanced light water reactor in a technology neutral fashion.

If I say it correctly so we really have a start where not really starting from scratch.

MS. DROUIN: Yes. And when I say we aren't going to have answers, what I mean by that is that as we expand. And I have gone through all and showed you all the places where we are going to be looking at. Is identify what we think the issues are and how we intend to go about resolving those issues.

MEMBER WALLIS: But you're going in to build the framework. Your objective is to build the framework. And there is someone like a bridge designer coming here saying I have a plan for building this bridge. And I don't really see you building the bridge yet. Because you are so far back in your development in the plan. That is what I have been saying.

And I am not talking about the whole program. I think you have parts of the program that is needed to be done which are important. I am just suggesting this framework. I sort of suspect that Jack is right. The framework is the key. To get the framework right, then that guides everything else you do. So I really would like to see a great framework.

The only reason I am asking these questions is I think you are a long way from saying here is our plan. We can see the framework coming. I don't see the framework coming yet. And I am reassured by Farouk saying it is a perturbation of what we have already. But that is not what some of your slides seem to say.

MS. DROUIN: I thought they were clear all the way through.

MEMBER WALLIS: They seem to suggest you are going to look right back at the beginning of regulations. Rewrite everything from the beginning. But maybe --

MS. DROUIN: But all the slides are showing we are starting with, all those pictures that you see are concerning framework.

MEMBER WALLIS: Sometimes they said that. But sometimes you were reexamining the goals and the cornerstones and the strategies and everything else.

MS. DROUIN: We will have cornerstones. We will have strategies. I mean that concept, that structure --

MEMBER WALLIS: I think you might make a decision today that the existing goals, cornerstones and strategies are a good basis for developing a framework. And then move on.

MS. DROUIN: But we have made that

decision.

MEMBER WALLIS: Well that is good to know. Then we don't need to keep hearing about it then. Make that decision and move on to the next stage.

MEMBER FORD: But Mary, I can understand what you have said. You said you take the existing one down to a certain level, the tactics level. And then take it as a given, there may be some questions about LERF and things of this nature.

But you are dotting the I's and crossing the T's on that statement is what is going to be done in 2002. The actual reduction to practice, checking on the PRA associated with those things, etc. That will not be done, as I understand it in 2003. The Commissioner said you will not do work on this in 2003?

MR. ELTAWILA: In the budget --

MEMBER FORD: Okay, so there could be a fourth bullet in that saying no work in 2003 on this particular issue?

MS. DROUIN: Yes.

MEMBER FORD: Okay.

MEMBER LEITCH: Have we muddied the issue? Let's take the case of a utility who, you know, project yourself a year or two out into the future, I mean relatively short term. As a early site permit approved. It comes in and says I want to put a AP-1000 on that site.

One of the important factors in a utilities mind in coming to that point is predictability of the regulatory process. Have we made the process less predictable. Would that be different if they came in 2003 versus 2005? With this new framework?

MS. DROUIN: I am not sure I understand the question.

MEMBER LEITCH: Have we introduced some confusion into the regulatory process that is what the utilities expectation of the regulatory process might be.

MS. DROUIN: I don't think so.

MR. ELTAWILA: No, because again, as I indicated earlier for advanced light water reactor of any kind, we can go and apply for certification based on the existing regulation. We don't have to wait for it. I think that will be benefit you need a different concept like gas core reactor and things like that. Will benefit more out of that framework than the light water reactor.

MEMBER LEITCH: So once again, the prime

driver for this is gas cooled reactors?

MR. ELTAWILA: Gas cooled or the other type of reactor that I mentioned earlier today.

MEMBER LEITCH: And if we are just dealing with light water reactors this change in the framework then, would likely not be done?

MR. ELTAWILA: I think it can be done either, it is being done under the coherence program. We are looking at the existing regulations to make themselves consistent and coherent in terms of their value and preparedness for risk.

So we are doing it, but again, as I mentioned to enlarge the playing field and include non-light water reactor and that is that what is the Delta we are talking about here.

MEMBER SIEBER: from the standpoint of the licensee, saying to myself. Do I understand what the basis for the licensing of an advanced reactor is, one thing that disappears for advance reactors out of Part 50 is all of the deterministic stuff. Since this framework really is a risk based system. I would think that once a licensee understood that, then that would be just as predictable as the old deterministic system.

MEMBER BONACA: The trouble is that this

framework is just a plan. I understand that it is not going to be worked on right now.

MEMBER SIEBER: No money.

MEMBER BONACA: I understand that. It troubles me because it means that you already saw Exelon coming in with a plan. At least they were proposing a framework of some nature and we had questions about that. There were a lot of good things about it.

And now we are going to wait for another person to come in with another proposal and another attempt to framework and everybody there probably wants to proposal design is going to struggle trying to think about where are we going to go with the regulation.

And I think it would be very helpful. In fact, my thought was that I was hoping that it would be a framework at least that licensees or potential licensees would look at and see different frames of it and then apply it within their proposals whenever they want to come into the concept.

MR. FLACK: Well, we're not really waiting. I guess a month or so ago we talked about the policy issues that were coming out of the designs that we have looked at to date. We are going up on a separate track on that one. And in the fall, there will be a follow up SECY.

That will talk about these policy issues and the resolution of those issues, pathways to resolutions and options and so on. It would probably be best in that context to think about what it would mean with the sense of a new revised framework, I would think. So it is not that we are waiting, we do have these other activities going on. We'll see how they develop and come forth in the fall.

CHAIRMAN KRESS: Where is the early site permitting being dealt with. That is not being done in research?

MR. FLACK: No.

CHAIRMAN KRESS: I think we need to get involved in that. We haven't been involved in that at all.

MEMBER SIEBER: So we understand the concept.

CHAIRMAN KRESS: So we understand the concept, what the criteria are for giving -- and how they are basing it. Anyway, I think this would be a good time to have a break.

MR. FLACK: Are you ready to wrap up?

MS. DROUIN: I'm done.

CHAIRMAN KRESS: You're through. So I will declare a 15 minute break. Please be back at 10:30.

MS. DROUIN: Thank you.

(Whereupon, the foregoing matter went off the record at 10:15 a.m. and went back on the record at 10:31 a.m.)

CHAIRMAN KRESS: Let's get started again.

MR. FLACK: Okay, our next speaker is Stuart Rubin who is part of the Advanced Reactor Group in the Office of Research. And his area is Fuels Analysis. So you will hear everything you want to know about TRISO fuel particles and associated issues.

MR. RUBIN: Yes, I'm a very tiny part of the advanced reactor research plan. And I am passing around a little of what those particles are. I haven't brought my pebbles because the plan was intended to be neutral with regard to specific HTGR fuel design. Whether it be pebble or prismatic.

And so, I should mention that although the presentation is focused on HTGR fields, advanced reactor research plan does have a piece on IRIS. And I can talk about that at the end if time and interest allow.

This first slide provides an outline of

what I will be talking about this morning. I will begin by reviewing the safety performance objective for the fuel. Its paramount role in ensuring fission product containment within the reactor system.

Next I will discuss the key issues, technical and research issues that were identified by the staff as well as by experts around the world in workshops and other forum that raised questions on the ability of TRISOP particle fuels to actually meet that performance objectives.

I will summarize the purpose and focus for the identified research needs. And then I will discuss the specific scope and content of our plan research activities.

In general, the research activities involve a radiation testing as well as accident simulation testing. Developing analytical codes and methods. And also developing staff expertise and knowledge in the are of fuel fabrication and how that relates to the fuel performance.

And then I will finally mention a few research projects and outcomes that we think will stem from this work.

As far as the safety objective, and this is not something that is written down, it's something

I put together myself. To begin with the, it is probably well known here, that the safety features and design characteristics of modern modular HTGRs are quite different from current generation LWRs. And first and foremost, among those differences is the all ceramic fuel element containing those tiny coated particles of fuel that are being passed around.

And by way of a concept, each TRISOP particle is in of itself a principle safety barrier. And the primary containment function for protecting against a release of fission products to the environment from all conditions of operations is design-basis accidents and accidents beyond that.

And so the fuel performance objective is to retain and contain those vision products at the site where they are generated within the fuel. And each withing those billions of particles that comprise a reactor core, a GT-MHR, PBMR cor.

And so because of the statement and position of reactor designers of HTGR's, that containment is essentially served by the fuel itself. There is a proposal or submittal of that the requirements for the reactor containment itself can be relaxed in terms of need to retain pressure and being leak tight.

MEMBER WALLIS: It seems to me, what you have just said fits right into the framework that Mary was talking about. There is no need to develop a new vocabulary or anything to deal with this new concept. Just to make a link to what we heard before.

CHAIRMAN KRESS: Well the framework had words like prevention and mitigation.

MEMBER WALLIS: Which we have here. I am just looking at it. It says barrier integrity and limit --

CHAIRMAN KRESS: The framework viewed those as separate things, prevention and mitigation. Here we have prevention and mitigation as one thing.

MEMBER WALLIS: That is okay, just as long as you combine features. You can combine the function and design.

CHAIRMAN KRESS: When you have --

MEMBER WALLIS: I felt that the framework was important. I couldn't understand why the Commission didn't spend the money on it. I'm just trying to put all these things into conceptual framework.

CHAIRMAN KRESS: I agree. I was flabbergasted that the Commission didn't want them to work on that.

MR. ELTAWILA: Again, it is budget. I tried to allocate the budget, so it was deferred for until `03.

MR. RUBIN: This next slide is intended to by way of background, provide some of the more important issues that were identified in these workshops and discussion within the staff and external stakeholders on what are the issues related to the question of whether or not TRISOP particle fuels can in fact retain fission products within the particles itself.

Some of the issues related to the adequacy of the historical irradiation test that were performed and perhaps not covering the more challenging operating conditions that we can expect in a modular HTGR. Such as in higher core operating temperatures, and also the fact that these historical tests may not have explored fully the safety margins during normal operation.

Similarly, there are concerns about the accident simulation testing. Whether they were sufficient to fully explore the safety margins. And for conditions such as even core heat-up, reactivity events, and chemical attack events, like air ingress.

There were also concerns and issues raised regarding the differences in fuel fabrication between the fuel that was made historically in Germany and performed very well. And the fuel that is yet to be made and knowledge that even subtle changes in a process for fabrication can cause significant changes in the fuel particle characteristics. Which play out as significant performance differences in an actual reactor environment.

And so there is work being done today to try to understand those links and how they connect. Also, questions involved the conservatism of the traditional testing methods that we used to qualify this fuel. Accelerated burn-up testing is typical of this fuel testing and other to get answers more quickly. But questions could come up whether or not that is conservative for chemical reaction failure mechanisms that may require more time to actually be seen.

Also the accident simulation test typically are a constant temperature type test, as opposed to actually tracking the time versus temperature. History that one would see in an actual event.

MEMBER WALLIS: You are talking about a irradiation testing. Where does burn-up come up in this?

MR. RUBIN: Irradiation burn-up would be associated with the irradiation testing. I am drawing distinction between the behavior of the fuel and an operating environment, fast fluence, burn-up operating temperature.

MEMBER WALLIS: My radiation that it has actually undergone a lot of nuclear reaction?

MR. RUBIN: Yes.

CHAIRMAN KRESS: Normally, all you have to do is stick them in a research reactor.

MR. RUBIN: A test reactor.

MEMBER WALLIS: But just irradiating doesn't simulate burn-up.

CHAIRMAN KRESS: No, they actually stick them in a neutron for a long time.

MR. RUBIN: Right. Burn-up is implied by the radiation testing. Other concerns relate to the ability to add analytical codes to actually predict fuel performance during normal operation and the ability to actually calculate temperatures in the core during normal operation and accidents.

And also, what were the quality controls that were used in those previous tests and how they compare with what we would expect today. And so with that background, this next slide provides the overall purpose of the HTGR fuels research.

First our focus is to more fully explore the limits for TRISO particle integrity and fission product retention capability. Both during normal operation/irradiation and burn up. As well as for the ability of the particle to stay intact in accidents that go beyond the licensing basis. And so as to more fully understand the safety margins in both arenas.

MEMBER LEITCH: Stuart could you help me with a question about my knowledge on this topic? Is TRISO a process or a manufacturers name. Or what?

MR. RUBIN: Okay, I brought a few pictures to actually explain this. On the right side, the one you are looking at there is a --

MEMBER ROSEN: Could you move to the side.

MR. RUBIN: On the right side, is a huge magnification of those particles that would be passed around.

MEMBER LEITCH: Okay.

MR. RUBIN: And then the TRISO refers to three layers principality that retain fission product. Going from the outward in, you have the outer Pyrolytic Carbon layer. And then you have the most important layer the silicon carbine layer, number two.

And an import of that is an inner Pyrolytic Carbon layer. Each has a fission product retention capability.

There is a fourth layer that is not part of the TRISO terminology and this a buffer layer to absorb fission gases to accommodate pressure build up in the fuel. And each of those layers is isotropic in terms of their properties. You get the TRISO for short. Trisotropic layers.

MEMBER ROSEN: Then in the center, you took us all the way through the buffer then there is this big hole, what is in the middle?

MR. RUBIN: Okay, that is way the way pay the bills. That is where the fuel is located. That is the fuel kernel, as it is called. Where you have either UO_2 in the case of a PBMR or UCO fuel in the case of GT-MHR. And so that is where the burn up is taking place, fission gases are being --

MEMBER WALLIS: This is just conceptual.

MR. RUBIN: No, this is an actual cut away, but it has been colorized at the uranium dioxide fuel kernel. There is the buffer layer. There is the inner Pyrolytic carbon layer.

MEMBER WALLIS: What I meant is it isn't a cartoon. It doesn't show dimension. It doesn't shoe tolerances on dimensions.

(MORE THAN ONE VOICE).

MEMBER WALLIS: But these again, these are all spherical.

MEMBER ROSEN: Wait a minute. You are not getting bogged down, this is the heart of it.

MR. RUBIN: Well sure, let's get going then.

MEMBER ROSEN: I wanted to know in the other picture. Will you go back to the other picture when you get a chance there. You can answer Graham's question and go back.

MR. RUBIN: The reason why I put that up is that shows some --

MEMBER ROSEN: That looks like to be kind of squashed. Do they all come out like that?

MEMBER WALLIS: My real question was are they spherical? There must be variations of manufacturers.

MEMBER ROSEN: Is that a real particle cut in half?

MR. RUBIN: I do believe that is.

MEMBER ROSEN: Or is that broad case? That is a real particle. It is a microscopic cross section. So we can see is that there is a lot of variability. It is not circular.

MR. RUBIN: That would come up in the part of fuel fabrication. Over the years it has been understood that it is important that the inner kernel is fuel maintain a sphericity power. In other words, the largest diameter, that is controlled in the fuel fabrication process.

And then they in turn you have coatings that are applied in a chemical vapor deposition burnup environment, and that deposition process is not uniform. It will be variations of thickness of it. It may be thicker over here than it is over there.

And again there are tolerances on what are the permitted variances between the max and the min.

MEMBER ROSEN: At 90 degrees there, it is very thin. At 270, it is quite a bit all the way up to 290 to 300 is quite a bit thicker.

MR. RUBIN: That is right, the particles are not perfect in their sphericity, the thicknesses are not perfectly uniform around the particle, but through radiation testing and pure analysis, design analysis, there have been tolerances that have been developed that provide for what is an acceptable variation from perfection in the thickness of the sphericity.

But the extent of that kernel is not perfectly, a perfect sphere when the coatings take place, that will drive larger variations in the coding thickness. So that is really a base starting point it is very important to get that kernel just as right as you can get it. If you don't you will see worse case outer thickness or thickness variation particles that miss. Okay, and there is a limit and I think on this next slide, there is some indication of what the -- no this doesn't actually show the tower. This only shows the means of those thicknesses. But there are towers that are according to the manufacturers specification. And there are tests, examinations that you could do on a sampling basis from each batch of particles to see if you are in those tolerances.

If you are not in those tolerances, you basically recycle those particles and start all over again.

MEMBER BONACA: I had a question on this thing. In your objectives you stated that the objective is to contain and retain the radiologically important fission products. Is there any gases which are being released through a normal operation of this?

MR. RUBIN: Yes. I say that because there is trapped uranium outside of the fuel particles. And there is also some uranium that finds itself in the outer layer due to manufacturer. And that uranium when it fissions, will give fission gas release and the only thing that is presenting that from escaping out of the boundary of the fuel element is the matrix material. And it is rather permeable to gases, fission product transport.

Now for gases that are generated inside the kernel, the concept is that those inner/outer Pyrolytic carbide layer and silicon-carbide layer will in fact retain those gases.

MEMBER BONACA: All right, I understand. Thank you.

MEMBER LEITCH: For some reason, we know enough that the research would be done on this TRISO fuel is going to be applicable. In other words, do we know that this is the concept that would be used in any gas reactor that would come forward. I mean are we sure enough of that that we can focus our research efforts on this now. Or is that still a subsequent decision?

MR. RUBIN: That's a good question. The information we got from PBMR or Exelon during the pre-application review is their plan for fuel design and manufacturer is to duplicate essentially the German particle design and pebble element design. And manufacture process as well. So, the particle for PBMR would be what I am showing here.

In fact, the dimensions I show on the other slide. And just in the side, the dimensions of those particles thicknesses are identical to the German reference fuel design that was made toward the end of their development process. For which there is a lot of experimental data.

Now as far as the GT-MHR is concerned, the plan, we have heard from GA, is to use TRISO particle fuel design. The thicknesses of the various layers will differ somewhat because of the kernel size. And also the application. However, they have said that they plan to follow the German manufacturing process as well for the fabrication of their fuel.

The biggest difference between the two concepts is the fuel matrix itself. As I said again, PBMR will be utilizing UO_2 fuel and GT-MHR will be utilizing UCO fuel. Uranium oxycarbide fuel. But the particle coatings will be essentially the same for both applications. Environments will be different that needs to be explored.

MEMBER FORD: Wasn't there a problem with carbon dust?

MR. RUBIN: The issue of carbon dust is not focused on the fuel research plan itself. The dust issue relates to fission product transport within the reactor system. And then exiting the reactor system as dust carrying off fission products in the case of a large break. And so there is a concern for, as a source term for whether or not that dust could be, should be included in the source term calculation.

MEMBER FORD: The reason why I asked just relates to Graham's point, I'd have thought that any OEM would want to reduce that. And therefore change the design of this coated fuel pallet.

MR. RUBIN: No.

MEMBER FORD: Just to give you a higher wear resistance. However it is going to do it.

MR. RUBIN: Again, just let me go back to this slide. The focus of this presentation is on what might be viewed as generic to both designs. Which is the particle itself. I think you are referring to the fuel sphere, which is the size of a tennis ball, I'd say. And due to motion through the reactor before creation of dust particles to the grinding action on the pebbles. And then fission product transport.

So that research plan is not focused on dust generation. However, I think as part of the reactor analysis part of this presentation, that would come into play there. In terms of how do we account for the dust in the source term, reactor systems analysis.

Well let me just try to keep moving here.

MEMBER LEITCH: I guess, Stuart, my question is basically, we know enough now to proceed with meaningful research or must we wait until the further resolution of the design?

MR. RUBIN: Yes, I think it is worthwhile to proceed if we research even now. Because again, although we have yet to have in hand fuel that is made from a production for use in a GT-MHR/PBMR. The reference fuel is in hand. And again, the particle design and the particle manufacturer of what we have in hand is to be followed by the vendors for those fuel to reactor types.

So we have a way to essentially benchmarking, if you will, what would be the safety margins for this kind of fuel with the fuel we have in hand. There are more similarities than differences and we can provide a benchmark in terms of particle integrity at high temperatures, high burn up, high fluence and also accident conditions.

And it would be useful then when the fuel for the actual reactors is available to prepare that benchmark against what how that fuel would perform.

MEMBER SIEBER: Would the agency actually be conducting basic research or would you be evaluating vendor research?

For example, all of the stuff has been tested in the past to determine its basic radiological/physical characteristics of the idea is to look at the test, I would imagine. To determine that the tests were valid, were conducted properly. And gave sufficient quality and quantity of data to these statistics.

MEMBER ROSEN: I am not sure your premise is right.

MEMBER SIEBER: Well that's the question. Is my premise right?

MEMBER ROSEN: Because you have named two different kinds of fuel. You said that there was a Uranium oxide fuel and an uranium oxycarbide fuel. Those are two different kinds of fuel. They would have two different kinds of interactions with the buffer and the rest of the TRISO particle layers. Is there a solid research and basis for both of those kinds of fuel? Both of those particles?

MR. RUBIN: Well, again, the research plan is really a plan that plays out over many years. And it starts with testing a fuel that is currently available which we think is important to do the testing on. The fuel which is currently available which is UO_2 fuel, TRISO particle fuel.

But then it moves over time, presumably when fuel for those specific plant designs are available to do a complimentary testing on that fuel. Okay, so this fuel is not the be all, end all test program. It is the beginning of the test program.

In other words, if you look at the plan, you will see test matrices for the fuel that is German archived fuel. You see test matrix for the production fuel for PBMR, if and when that is available. And then you see test matrix for fuel for the other design.

So you rarely over the course of the research plan will be looking at all of --

MEMBER ROSEN: Try to answer my question. My question is, based on my understanding that there is a lot of data available for TRISO coated particle fuel performances for uranium oxide particles. And that in that sense, the staff, for that fuel, the staff would be looking the data. Now change the subject, is there a similar database for uranium oxycarbide fuel? Or is that totally new?

MR. RUBIN: No, it is not new. There were relatively few irradiation tests and accident simulation tests done on oxycarbide fuel in Germany. The database for UO_2, TRISO particle fuel is much, much larger than UCO fuel. That is a point of fact.

MEMBER SIEBER: Now, this testing involves the particle, but not the fuel elements themselves, tennis balls or whatever they turn out to be. And that testing, to me, would be important for the thermal hydraulic standpoint in predicting what the ultimate temperatures would be during accident conditions or loss of coolant accidents. That actually is related directly to the reactor concept as opposed to the individual components of the fuel. Which are releasing tiny particles. Is that correct?

MR. RUBIN: Let me say that the fuel testing in all cases, will be carried out, not as loose particles, but as particles within there specific fuel elements. Okay, so the initial testing that is envisioned for the German archive fuel will be done on TRISO particles in a pebble bed format, you might say, a fuel element.

But the primary interest is on the behavior of the particles within that fuel matrix.

So, we do in a way get the performance characteristics of the fuel by testing it that way. And we would be measuring fission product release. Or we need to measure fission product release coming off of the fuel element itself. Which is an integration of releases from particles in tact and broken as well as from the matrix.

But the plan would be to focus in on the performance limitations or integrity limits of the particles themselves within, whether it be a spherical element, a pebble or a prismatic element, a compact.

CHAIRMAN KRESS: When you have a actual rule that says that this reactor will not release so many fission products because of the site location and stuff. The rule will be backed down to certain qualities of fuel. In terms of how many of these particles not be failed in the first place. Track how much uranium is in there. And how much particle may be defective and actually release more than the standard particle.

There is so many particles in loading the fuel, that there is no way you can know ahead of time other than by looking at the process in which it was made. And looking at the batch thing to see if the tolerance is there on the dimensions. But there is no way you can really know for a batch of fuel that is coming in that meets these quality specifications. It has to meet the regulatory requirements on the release rate.

My question is, is there anything in the plan that says, okay, when we load this fuel, I am going to start looking at the build up of activity of the coolant system to see what it is in terms of rates and what the isotopic mixture is and stuff. And I am going to confer from that, whether or not I am meeting my fuel quality standards during the initial operation.

Is that in the plan anywhere or, because that is basically what we do with the fuel now. And I am wondering if we have any research plan a way to look at that as a concept to as we say, yes you have met the fuel quality that we expected you to meet?

MR. RUBIN: The research plan is not focused in on the integrated fission product release question that might be measured by a coolant activity monitoring system. But, what we are interested is in the understanding whether or not such a coolant activity monitoring system is really capable of detecting what you might call incipient or latent failures of a fuel. A weakening of the fuel.

So, certainly if one can show that the monitoring system is capable of detecting failures that actually occur in the radiation, we would want to understand how the measurements are actually taken can be back tracked into the actual fuel performance determination.

But this research plan is not focused on that kind of integrated issue. It is really focused in on can that monitoring system detect failures before they might announce themselves in an actual accident situation. That is a question.

MR. FLACK: Yeah, I think the question on the correlation between you know, vision product release for a normal operation is an indication on how the fuel performed during an accident is a good question. And we have talked about this many times. But whether there is in fact, a correlation, and how we are going to go about determining it. And it is not in the plan to say well we plan to look at normal operation and vision product behavior during that. I think that will come as part of the operation.

The question comes down to can it be predictable from the model that can be generated about the fuel fabrication. And then from that, understand how the fuel should perform during normal operation.

And then, understand whether or not from fission product release into the coolant, predict what the performance would be during an accident.

It is a very good question and it is something we have been discussing about. We don't know how far these models will ultimately take us. Bur as far as trying to understand the fuel, and what's important for fabrication, I think the best we could do now is look at what these models will tell us and predict.

CHAIRMAN KRESS: But it is in your thinking?

MR. FLACK: It is in our thinking. I constantly talk about it quite often, so.

MR. RUBIN: Okay, let me -- I don't know where we ended up, let me go back to this slide first. The objective for the -- let me back up one more time. The purpose.

Again, the purpose is to understand what the safety margins are within the fuel. Again, the testing that was done in Germany and around the world for that matter was really focused in on showing performance being acceptable within the licensing basis. That is predominately the philosophy of fuel testing that we have seen.

What we are interested in is testing outside the licensing basis to find out what the failure point of the fuel margins are. The fuel qualification testing that an applicant will submit will again focus in on fuel performance within the licensing basis and maybe a little bit beyond that.

But they are not interested in showing failure points. That is where we come in. That is where our focus is in understanding where those failure points are. And so that is one of the key aspects of the plan.

We also think that the research is by actually doing this, will enable our staff to better assess the validity of the applicants claims of fuel performance in terms of failure and fission product release. We think they will also strengthen our knowledge and information about how you actually do a radiation testing.

And let me just jump down. And finally we think the research plan includes activities that will provide the staff with, I think an essential understanding of the relationship between how fuel is made. How that process turns into actual fuel characteristics or properties that then play out in terms of actual fuel performance.

MEMBER ROSEN: Stu, hold on a minute. There seems to be a little confusion here. At least in my mind. Maybe you and Farouk can help me.

Earlier we talked about licensing basis and beyond licensing basis. Here, and I think Farouk may a very important point that in the risk informed license world, we will have a smoother continuum. We won't have this cut off point between licensing basis and what is beyond licensing basis.

Yet in this discussion, you seem to imply that there is this firm cut off date. That we want to know what is going on within the licensing basis and beyond. And so what would help me understand why one part of the discussion we hear that no black and white situation, we have a continuum. And another part we hear there is. I don't get it.

MR. RUBIN: Well, from what we have seen in terms of the proposals from Exelon and we have been told by GA that they are going to plan on following in Exelon's footsteps, is that you essentially have a frequency versus the kind of consequences type mapping.

And from that mapping there are bands which have been identified for what the frequency between, let's say once per year, to so many times per year is defined to the normal operation. Is the frequency band and they just label it as such. And there are consequences that are associated with that.

Then there is another band of less frequent events that pick up where the normal operations frequency ends. And drops it down to a lower bound of frequency if you will, that defines what they would call the design basis events. And then below that band is events that are considered for emergency planning basis beyond the design.

So I think the two kind of work together. It is just a way of labeling those bands and that is how I labeled, that is the framework that I am talking about. It is a continuum, but I am just making reference to the normal operation being in that frequency range. Design basis events being in the lower frequency range. And then the events beyond design basis, for example, air ingress events may be viewed as beyond a design basis for some plants.

But we are interested in other standards, fuel performance anyway. So we understand what margins they exist. Should that type of event occur.

MR. FLACK: From our perspective, we look at the fuel as saying, well if the temperature is below 1600 degrees, let's say. On the average, for most of the challenging events that Stu has just described. They will go as far as, and here is where the difference of philosophy comes between where the regulatory perspective comes in and an applicants perspective comes in.

The applicant will say, well we have margin even beyond 1600 degrees and go on about to demonstrate their margin up to a certain point. For us to fully understand how the fuel is going to behave, we would take the fuel to failure for example.

We wouldn't necessarily stop at 1800 we would continue to test up until the fission products came off at a certain rate. At what rate and what temperature. And in that way, understand how the fuel really will behave under maybe more severe conditions than we can ever imagine.

One of them may have been an air ingress event which licensee would consider a self low and the frequency that we no longer consider that to be a credible event. And therefore we won't look at that.

We'll only look at these events of higher frequency, which are still pretty low. And they may very well be. The question is, do you want an infrastructure in the regulatory commission that understands how this fuel performs under all conditions and is comfortable with that fuel and the point at which it will really get to unravel. What temperature, over what periods of time and so on.

So that is more of the perspective for us to take things all the way to their limits. Not to be satisfied at one particular margin limit which an applicant might demonstrate with data. Of course, we are certainly interested in that.

But there are other conditions, just from the sake of regulatory perspective, to cover our own knowledge and understanding of the fuel. And so that we are not left with, well what happens if the fuel goes higher in temperature. What is the ramification?

I a mean, I think we do need to look there. And from there, I think you start to see the difference in philosophy between a regulator in an applicant.

MR. ELTAWILA: There is no difference. I think John said most of the stuff that I would have said. However, it is not a philosophy difference between happily content NRC. That issue we raised it to the policy level issue. We are asking the commission should the NRC require a licensee to administrate fewer performance under all the spectrum of accident, including severe accident.

In the past, we did this work ourselves as John indicated. But for in the future, we are raising that question to the commission to get some guidance. You know, because if the commission says yes that would be a requirement, then the applicant and the licensee would be required to test that fuel to failure.

MEMBER BONACA: It seems to me also that it could be the critical element in support of the confinement versus containment. What I mean, is that if you could demonstrate not only the applicant says he can't get beyond 1800 degrees Centigrade for example, and under certain conditions, it excludes certain events that is possible.

And you can prove that you can go 3000 degrees to make a number. And you cannot get there in anyway, it seems to me that would be a fundamental decision point that says you have confinement. And confinement is totally adequate. So I think in this case, it seems to me like it is an issue that goes beyond just the fuel performance per se as we have seen it in the light water reactors.

It goes into the role of confinement that or containment. Really we attributing to the matrix, the fuel matrix.

MR. FLACK: That is a good point.

MEMBER BONACA: It seems to me that would fall under physical challenges that are out there was that.

MR. RUBIN: Just let me say that the way plan is put together and the way I hope to talk about it, is in terms of needs. Whether or not ultimately the commission policy will be that those needs need to be met by the applicant. They need to do this research whether or not we are not going to require that.

And we would do the research that question is part of the policy issue. But the need to explore the failure points is valid. That has not has been explored and argued sufficiently.

And so just to talk about the scope of the research, it really involves these five areas, the radiation testing, accent condition testing, development of analytical miles and methods for predicting fuel performance and fission product release. Developing knowledge of a fuel fabrication process and how they relate to particle characteristics and performance. And then generally to develop our level of knowledge across all these areas.

MEMBER FORD: Stuart, you said earlier on that this work could go on for quite a few years?

MR. RUBIN: Yes.

MR. ELTAWILA: The first two bullets, especially. They are going to be time consuming in reactor work. Is that work, is it going to be done by the NRC with contractors?

MR. RUBIN: Well I was going to get to that. The strategy for how we would do this testing. That comes up under the discussions of how we would actually implement the irradiation testing. My response to your question will just come out in the wash in the presentation.

The answer is we are going to try to enter into cooperative research and coordinated research.

MEMBER FORD: Does that mean before, several years before you come up with the criteria that the applicant has to meet. There is going to be several years before he can even start to obtain the data to resolve, to meet those criteria.

MR. RUBIN: The focus this research is not necessarily to develop the performance criteria. We expect that the applicant will propose what are the operating and safety limits of the fuel. And then to go about doing analysis and qualification testing to show that the fuel will perform in terms of very limited fuel particle failures up to those limits.

And then in turn, you take those results from the testing plan and you put it into your analysis of consequences. And ultimately the criteria is the radiological consequence levels that we have. So there is no need for an applicant to wait for our testing to be completed.

MEMBER FORD: This is where General Atomics have been doing research, which obviously you must have been. And they are coming up with defining a certain performance criteria for their fuel pellets. What happens in two years time because the regular framework aspects and then later you come up with completely different criteria. In order to meet the risk informed aspects of this design. That means you are going to start again.

MR. FLACK: Well I don't think you would have to start again. I think a lot of it goes back to the question that was raised earlier, a comment made by Jack.

And that has to do with regulatory decisions and how confident you are in making those decisions and how much defense-in-depth you will need to implement into the plan.

And the more we know about the fuel behavior, the more we know about the plan, the better informed the regulator will be in making those decisions. If we say, well wouldn't carry on a test program now, we will wait until the design comes in. And then when the design comes in, now it is like, well now these questions need to be answered.

How are we going to make decisions? Now we are left with how many years in the future are we going to have the answers to these. And then what we are going to have make decisions now based on the regulations in place and here is how we are going to do that.

I think the whole thing is in preparing ourselves now for those decisions in the future. And where we are. I mean we will always make a decision. The question is how good of a decision can we make at that time.

MEMBER FORD: The sooner the start, the better you are going to be.

MR. FLACK: Right.

MEMBER RANSOM: The question I had is does DOE have any role in the research in general. You know they have the NERI programs?

MR. RUBIN: Again, that is coming up in a slide just to mention it now. DOE has a HTGR fuels development and qualification test program that they have funding for.

And the elements of that program include developing fuel fabrication technology for the manufacturer of TRISO particle fuels and compacts or pebble format. Also for development for analytical codes for predicting particle failure and fission product release.

The last major area relates to irradiation testing and accident simulation testing of fuel. And it is that activity that the NRC is looking to enter into a cooperative irradiation testing agreement with DOE to test fuel. So, we think there is an ability to leverage our resources.

MEMBER RANSOM: So you're complimenting what they do or it is integrated, I guess?

MR. RUBIN: Well we have established our test objectives in terms of where we want to explore margins. And they have established our test objectives and we see where they might be overlapped. And we can take advantage of what they have planned, but we anticipate there is going to be stuff that we want to do that they have no interest in things that they want to do and that we are not interested in.

Because it maybe within the design basis environment.

And so, the idea would be to enter into an agreement with some cost sharing to equitably pay for the entire integrated tests together. And share all the data.

MEMBER WALLIS: How do you know what this design basis is until you have some regulation?

MR. RUBIN: Well, the -- we have in terms of PBMR, through the pre-application review, some information as to the fuel design basis. Sixteen hundred degrees, we have been told is anticipated to be the accident limit.

The burn up level for the fuel is I believe is 80,000 megawatt days per ton. We have some information on what the fast fluence is for our fuel as a design limit. The one variable that we have, we are not sure of is the maximum fuel operating temperature in the core.

And that was kind of increasing as we went through the pre-application review as they were sharpening their pencils. And taking account of issues that were identified. But now all that maybe have to be thrown out because the latest information is that they maybe going to a solid core, rather than a graphite pebble core.

What that does is it will serve to lower the operating temperatures of the hottest fuel in the core. And so, we don't know exactly where they may be on fuel operating temperature. But we will have to pin that down before we start testing.

But I will say this, that our range of testing for operating temperature in my mind should significantly exceed what they are going to come up with. We are looking at 1400 degrees C as a maximum operating temperature for irradiation. And they are likely to be below 1250. So we will have 150 perhaps more margin testing on temperature.

MEMBER SIEBER: Actually the fuel element temperature, average fuel element temperature peak is one factor, but you also have to consider the temperature of the vessel that holds all this stuff. And if you had an accident temperature that was up like 2 or 3 thousand degrees C, then one wonders how long it would take for the reactor vessel to fall apart and everything go to the floor and from the floor to wherever it goes. Which is the other half.

MR. FLACK: That's right, you will hear about the materials presentation shortly on some of them.

MEMBER SIEBER: To me that would be an

important factor. Because this fuel is pretty robust being it is a ceramic. You know, in every kind of engine you ultimately run into a materials problem that says this is as far as you can go.

MR. RUBIN: Well you mentioned that the fuel is pretty robust, I think at the April 11 ACRS meeting on the plans the statement was made the fuel never fails. This slide is intended to just dismiss that notion by providing various mechanisms that have been identified over the years for particle failure and fission product release.

I won't go through them, other than to mention, I have tried to label whether or not those mechanisms are driven by environmental that is temperature, fluence, burn up, type, processes, or whether or not they are driven by, let's say manufacturing causes.

And so you can see there is a whole host of a failure mechanisms and fission product release mechanisms that have been identified for this fuel.

MEMBER ROSEN: Wait a minute, what does Opy C mean?

MR. RUBIN: Outer Pyrolytic carbon layer. And inner Pyrolytic carbon layer.

MEMBER ROSEN: Heavy metal contamination

of the graphite matrix or outer Pyrolytic?

MR. RUBIN: Again, as I mentioned earlier that there is trapped uranium that you are going to get just by using the natural graphite in the matrix. The release of uranium in there just naturally occurring and that will be part of a source of fission products. And then there is uranium or heavy metal that will contaminate the outer layers simply by the process that is used.

The initial kernel uranium will find its way through the reuse or the multiple layer coatings in the vapor depositing furnace will show up on that outer layer. And then when that fissions that will be seen as a fission product release element.

MEMBER FORD: I noticed that environmental dominates that list. And therefore you are concerned about mass transport connections and things of this nature. I remember at the commission meeting Graham said advanced reactors are going to be a give me. Because it is going to be so easy to resolve all of these mass transport equations for a single phase system.

Is that true. Do you see any big concerns about mass transport modeling for these systems? And therefore sending a patent to an --

MR. RUBIN: Yes, the equations that have been used in Germany are fairly well recognized diffusion equations and have been best fit to the test data that has been developed from irradiations.

I am not sure we are going to push the state of the art beyond the use of those kinds of models. We would want to develop our own test data to fully understand that these models that they would be proposing are adequate.

MEMBER WALLIS: I would think there was something between the pressure induced failure and diffusion then there must be mechanisms for cracking or other things to happen to the coating by which it would loose some of its integrity.

MR. RUBIN: Yes.

MEMBER WALLIS: Which would some time be somewhat mysterious until you have done the research.

MR. RUBIN: Yes, there is a whole host of mechanisms including, by the way the comment that the failures are dominated by the environment is not necessarily to be a conclusion to be drawn from this list. Although there are a lot of environmental lines up there.

If you take a look at the radiation performance of German fuel and compare that to the irradiation performance of U.S. made fuel, you would see about two to three orders of magnitude difference between the fission product release of those two fuel types.

MEMBER ROSEN: Which is higher?

MR. RUBIN: The higher being the American made TRISO particle fuel. And in recent studies that have been conducted have concluded that the differences in the manufacturing process for the manufacturer of those particles which result in differences in the particle layer properties and the bonding between layers is a very, very important, if not dominate factor in how particles will perform in the reactor.

And so although the environment will actually push those particles to failure, it kind of begins in a way with how you made those particles. And that by the way, understanding how you make particles and achieve the necessary characteristics, is a large world wide effort that is ongoing right now. Both DOE and the European Commission and others are trying to understand how manufacturing processes give rise to particle properties which give rise to performance.

Knowing that if you just make it the way you thought they made it, it will work out. There is a lot of devil in the details of the processes that are used. And that seems to be the big issue Areas in particle performances in manufacturer.

MEMBER ROSEN: Is there also a silver migration problem here?

MR. RUBIN: The silver 110M, that is pretty much not contained within the particles. And so silver 110M will migrate out of the particles through the graphite matrix and out into the system. And ultimately will adhere to the coal surfaces principality on the balance of plant surfaces. And then that becomes a occupational dose kind of a concern as opposed to an off site radiological concern.

MEMBER ROSEN: What is it about that isotope that makes it different from the other isotopes?

MR. RUBIN: That is an area where there has been speculation as to why those particle layers are somewhat permeable to that. I don't have an answer. I don't know that anyone has an answer to that other than they measure it and it happens. There are theories, but they are just theories.

MEMBER ROSEN: Are you going to research

that?

MR. RUBIN: Are we going to research the causes?

MEMBER ROSEN: Why it happens and what can be done to prevent it?

MR. RUBIN: Well, let me say this, there are two principle ways to reduce it. It is driven by diffusion processes which is driven by temperature differences across the particle and across the pebble. And one way to reduce it is to reduce the operating temperatures of the particles.

The other way to reduce it is to thicken the silicon carbide layer. It does provide some barrier to diffusion. So those are the two principle ways to do it. However, since these are high temperature reactors and they are trying to achieve high temperature gas temperatures for various applications, including power generation, I don't think they want to reduce the temperature of the fuel necessarily to a point where a silver 110M is going to disappear.

The approaches we have seen recently is that managing the consequences in terms of how you manage the maintenance of these balance of plan equipment to deal with that. But not to reduce it by containing it within the fuel itself.

MEMBER ROSEN: Let the operators handle it.

MR. RUBIN: Well one of the plans we have seen is to have kind of a package where you pull out the turbine generator out of the plant. And you put it aside and put a new one in its place. That is uncontaminated. And then you wait for that contaminated one to kind of pull down if you will and then after a year and a half or so, you do maintenance on it. As opposed to try and do maintenance on that one turbo generator.

MEMBER SIEBER: But see, solar is only one factor. The carbon dust has got trapped uranium in it. And I am sure there is tons of crud traps in the balance in the plants where all this stuff would collect.

MR. FLACK: Yeah, but it's not a missed point. The plan does recognize if from a LARP perspective, as an issue. And then the question of how far down in detail do we need to understand this from a risk perspective, I don't know.

It is there. It is something we are going to have to look at from regulator, from a regulatory perspective. And how much effort we need to put into it is still yet to be determined.

MEMBER ROSEN: Why wouldn't you tell the vendors to come back when they know how to control the silver?

MR. FLACK: If it's from a risk perspective, that is the indication that we get. That may be a message back. But right now, I don't know if we are in a position to give that back.

MEMBER SIEBER: That sounds deterministic to me.

MEMBER ROSEN: Well we rationalists often get deterministic. We have streaks of determinism in us.

CHAIRMAN KRESS: Yellow streaks.

MEMBER ROSEN: That's right.

MR. RUBIN: Okay, just real quickly. In terms of exploring the limits. We want to push the fuel beyond the design basis certainly and these are the kind of parameters that we are looking at. Temperature to fuel during irradiation. The burn up of the fuel. Fast fluence. Power in the coated particles.

Again the testing that has been done historically, you are looking at about 80,000 megawatts days per ton, perhaps 1100 degrees C. And let's say four times ten to the 25th neutrons per meter squared of fast neutrons.

And in Germany, good fuel performance was observed with those conditions. But what we are looking at is pushing those parameters much higher. Perhaps 20% FEMA, 1250 to 1400 degrees C, and burn ups double what have been seen or tested in Germany to kind of address the gaps in safety margins.

And again these will involve coated particle powers higher than one would see in a reactor since we are going to be irradiation testing on accelerated basis in this field.

MEMBER LEITCH: Stuart, are you planning to look at fuel performance in non stress conditions. In other words, just coming out of the manufacturer shop, how good is the fuel?

I am not talking about under stress conditions. I mean, just come out of the shop, might there be imperfections in the fuel. Are you taking a look at that at all?

MR. RUBIN: In terms of looking at the fuel, we have to think in terms of what fuel that we have to look at. And the fuel that we have to look at right now, is again the German reference archive fuel and we do expect to do pre-irradiation characterizations of that fuel before we irradiate with, I think we have more fuel than we are going to irradiate and we use that fuel for pre-irradiation characterizations.

We already have, you might say the manufacturing sampling statistics on the various QA tests that are done on that fuel. So we know in general what the statistics say. But we ought to be examining the particles.

Now for the fuel that is yet to be made, there is not much we can do right now to look at that. Since that is years away. But that is part of the plan is to do pre-irradiation characterizations of all the fuel that we are testing.

MEMBER FORD: Stuart, would you mind going back to the previous graph. If you looked at those four factors there, and refer back to the previous one where you got a whole list of all the potential performance and things. You have got a huge x by x matrix of all the interactions between the previous one and those four items.

How do you prioritize as to which of these aspects you must look at in the first year? What is your prioritization strategy?

MR. RUBIN: Well, it is kind of what you

see is what you get in terms of the actual mechanisms that will play out in the environment. And although these are the drivers for seeing those mechanisms, not all mechanisms will be seen by the fuel. Because we may not get to the temperatures necessary to where some of these mechanisms are active.

MEMBER FORD: For instance, the probability of having a certain defect density in your fuel particles would impact on what the allowable highest irradiation temperature would be. And so on, you could go on first and second and third order effects.

Are there algorithms to tell you what your prioritizations should be in terms of doing these very expensive tests?

MR. RUBIN: Well, again, we are looking at specific fuel design. As specific manufacturer for that design. And then subjecting it to a particular environment. And that specific manufacturer will give rise to variations as you said.

And those will be imbedded into the actual tests due to the fact that you have perhaps 15,000 particles in each pebble I would say. What we will see, for example, under disassociation at high temperatures. I don't expect we are going to see that, because we are not going to get near the temperatures where that mechanism would show up. Certainly not during operations in the accident temperatures were envisioning of say 1800 degrees maximum. That wouldn't show up there either.

You would see that in the starting out, let's say 2200 degree C. So we wouldn't see that. We will see what failure mechanisms occurred, if any in the PIEs. That is the purpose of the PIE is doing examination to see what the condition of the fuel is and what really happened in terms of particle failures.

Were they failures where there were cracks in the outer Pyrolytic carbon layer that then progressed into cracks not the silicon carbide. That is to say a high stress region occurring in the silicon carbide. Do we see Palladium attack. We'll see that in the PIE's. I don't expect to see Palladium attack in these experiments because the amount of time and temperature involved is again, a far in excess of the licensing basis conditions for any PBMR, certainly.

The test is not designed to test fuel where every particle is identical. And then go through a variation of environmental conditions.

MEMBER FORD: That is not practical. That is not achievable. The strategy you are outlining seems to be we will take what we get. In other words, you are taking a spot stab because those happen to be the conditions you have. But you can't extract from those conditions and say look here for that reactor or that design by that manufacturer, United States manufacturer versus German manufacturer.

You can't do the extrapolation from that data point to those conditions. I think that is true.

MR. RUBIN: I think there is a truth in what you say. Certainly because of what I said before that manufacturing will drive performance in large respects. But again, the reference fuel that we are testing is the reference fuel for these new designs so it establishes a bench mark, if you will, on capability of this fuel.

MEMBER FORD: But there is no way of doing a PRA or because you just don't have the data?

MR. RUBIN: Well if we were to test --

MEMBER FORD: A lower level PRA.

MR. RUBIN: If we were to test this fuel as they have tested it historically within let's say the design envelope for the fuel. In Germany, they saw no fuel failures during irradiation testing within a design envelope. And even a little beyond that they saw no particle failures in the accident simulation testing.

I mean they are very proud of those results. We want to see if we can drive the fuel to a more challenging operating conditions and more challenging accident conditions. And to see where we start to see some statistically significant up take if you will, in the particle failure rates. But the actual mechanisms, we won't know what they are until we do the PIE.

MEMBER WALLIS: Well finding out the mechanism may not be so easy. I mean you have got all these myriads of particles in some kind of a matrix. And then you find you have got to detect some radiation somewhere.

You are going to take everything apart to figure what happened? Look at every one of those particles? What are actually going to do diagnostically?

MR. RUBIN: Well there are mechanisms to, if you will, take apart the matrix material.

MEMBER WALLIS: Then you have got 15,000 particles, all which have failed in various ways.

MR. RUBIN: Well, we don't expect that

they are going to fail in various ways.

MEMBER WALLIS: Well why not?

MR. RUBIN: Well --

MEMBER BONACA: One concern I have, by the way, is --

MR. RUBIN: We could drive through all of these failure mechanisms if we had in hand fuel that, let's say was, made by the U.S., okay with our manufacturing. And we were to drive the fuel up to places where we know it is definitely going to fail. Up to 2200, 2400 degrees C. Or if we take it out to burn up, if we could, to 200,000 megawatts days per ton. We know we will see a significant fraction of failures.

MEMBER BONACA: In manufacturing, how do you assure uniformity of distribution of the 15,000 particles in the spherical? You may sample it. But I am saying this too, you have to deal with the possibility that you may have lumping of particles in some location rather than others. Which means that in certain locations you could decouple almost a sector with a much higher density that co-responds to 30.000 particles and vice versa somewhere else. You have the equivalent of 7,000 parts.

So, I am trying to understand how you deal with those issues in this matrix because, what I am trying to say is that the matrix may be even more complicated than what you are presenting here.

MR. RUBIN: Well in any test program, you are going to be testing a sampling of the manufactured fuel. And that sampling will have had to have met the production QA requirements in terms of a sampling rate. And what the measured variance was and what the mean was in a particular parameter.

With all that, there will be some pebbles that will have initial particle defects in them. And there will be some pebbles that have no initial particle defects in them. And there will be pebbles that have perhaps more particles with thinner layers than other pebbles have.

We will be dealing with the manufacturing QA results for the batches of pebbles that these fuels came from. Beyond that, we don't have an ability to be more precise in knowing what the exact distribution was on these particular pebbles in terms of the --

MEMBER BONACA: So you are not going to attempt -- it certainly would be interesting to have some pebble that has 20,000 particles in it and some with 10,000 and see how they -- the challenges here and that would give you some idea of how this changes in distribution may affect performance.

MR. RUBIN: I don't have a, perhaps, Don can help me out there in terms of the number of particles within a pebble. Or the number of particles within the compact and how that would play out in terms of temperatures and temperatures in effecting fuel performance.

But I think our analysis of difference in the number of particles in a pebble was not a significant driver of fuel performance in reactor. And that was due in large part due to the temperatures that the individual particles would see during operation. Would not be significantly different.

If you had 15,000 or you had 17,000 particles in there. So that is not a large factor, if you will, in particle failure phenomena. Is there something you would add?

MEMBER SIEBER: That is easy to control too.

MR. RUBIN: That's easy to control. That is true.

MEMBER SIEBER: Weigh them, see how much they weigh.

MEMBER BONACA: No, I am not talking about, I am talking about only changing the number of pebbles to test the density of particles that may be higher in some location or another.

MEMBER SIEBER: You mean within the pebble itself?

MEMBER BONACA: No, no, I am talking about --

MEMBER SIEBER: From one pebble to another?

MEMBER BONACA: When you mix using the matrix, you have 15,000 particles. That is easy to control. But am saying that you are not sure how distributed they are. They may be lumped together in some area rather than other. And you know, in that particular area, you can almost conceive it as decoupled area with more density than some.

MEMBER ROSEN: I think you see that right there Mario, in the picture that is showing. There is an area where there are very few pebbles.

MEMBER BONACA: You're right.

MR. FLACK: Just to try to get us back on track a little, there is a lot of questions. And the approach of the plan is first find out what was all done world wide in all these different areas. Try to get as much information as we can. And part of it is opportune. What we can do now within our budget.

What is the best thing to do. It is an integrative process as well.

As we learn more, we will be asking ourselves more questions to try to keep it focused. But as the discussions have been, it is a complicated subject. And it is just there is not a simple answer. There is a lot of parameters that need to be controlled.

CHAIRMAN KRESS: Well one comment I might have is, I would start my thinking from a viewpoint of what analytical tool I am going to be using. And it is probably something like MELCOR. And if you looked at the fission product release models from fuel that are in MELCOR now, they are all empirically based.

They are not mechanistic at all. They are empirical.

MR. FLACK: Sure.

CHAIRMAN KRESS: So I would say now, if I want to put in a replacement model for in MELCOR for fission product release, I have my choice. Am I going to use some sort of mechanistic model that talks about mechanisms of failure of the fuel. And how that is related to temperature. I don't give much hope there.

I think you are going to be empirical again, which tells me you are going to do something like separate out the influence of tramp uranium, for example. And already failed particles. They are going to behave differently in an empirical manner than the pebble beds that are in there -- that are already good.

But what are there behavior going to be when it goes through some sort of transient nitrites that have been in a radiation field for a long time. So I would say if I was going to redo MELCORs models, I would trade tramp uranium and failed particles differently then I would intact particles. And then my experiments, my research would be empirically based and I would be looking at full fuel elements.

MR. FLACK: Right.

CHAIRMAN KRESS: And what happens to them when they go to a temperature transient and translate into a fission product release model of some kind.

MR. FLACK: Sure.

MR. RUBIN: I would say that the fission product transport and release models for fuel do account for the tramp uranium as well as release from the outer coating due to contamination of that. Possible diffusion through intact particles and release from broken particles. So there are a number of terms --

CHAIRMAN KRESS: I would accept separate terms.

MR. RUBIN: Yes, there are many separate terms that one could look at in those codes. Just very quickly, given those irradiation test conditions, we would plan to do two things basically. Monitor fission gas release as a measure of diffusion of fission products of intact particles and release from failed particles.

And also, again, we would plan on doing PIEs to better understand the fuel condition and more specifically what were the failure mechanisms that were --

MEMBER WALLIS: How do you tell the difference between fusion and failure? It gets out, but how do you know it got out?

MR. RUBIN: Well if you are looking at 15,000 particles in a pebble and each pebble is individually monitored for fission product release, what you will see in a fuel with all intact particles, is perhaps in the order of ten to the minus eighth R over B ratio of krypton release.

MEMBER ROSEN: What is R over B?

MR. RUBIN: Release to birth of a particular. In other words, the release fraction of particular radioisotope to the birth fraction. Okay. And that history over the irradiation has a signature which is so low that essentially says, you don't have a particle failure. Now when a particle failure does occur, you will see a significant --

MEMBER WALLIS: So it's all or nothing?

MR. RUBIN: Into the range of ten to the minus five.

MEMBER WALLIS: It's all or nothing. You don't get partial failure, you don't get slight weights.

MR. RUBIN: Once that particle, the first one goes, you will see the step change in the curb. And I think I might have brought --

MEMBER WALLIS: Okay --

MEMBER ROSEN: That is one of the 15,000 particles goes, you see it.

MR. RUBIN: Yeah, you'll be able to get a good handle on the numbers based on how that curve goes. I don't think I have one here that shows that, no.

CHAIRMAN KRESS: We saw a curve of a number of particles versus failure versus time at a given temperature --

MR. RUBIN: Yes and this one doesn't show it as clearly.

CHAIRMAN KRESS: It is something like that, yes.

MR. RUBIN: These curves down here would be typical of no particle failures. If you take a look at R over B from one particle failure out of let's say 15,000, you have to be up in this range up here. So around here, you would be talking about one particle failure.

MEMBER SIEBER: It would be better if you sed the microphone.

MR. RUBIN: I'm sorry. The 1700 degree family is an indicator of multiple particle failures. The 1600 family is indication of no particle failures in this fuel.

MEMBER WALLIS: That's so far. But you might get an American fuel which it is so bad that it is porous and it doesn't fail at all, but it is up at 1700.

MR. RUBIN: This by the way is for an accident simulation, but for, if you can imagine this at irradiation time and release of krypton, then you would see it. This is an R over B ratio. Such as you would see perhaps a spike going from this curve up to that level. And then if you had more particle failure, it would start to change.

MEMBER WALLIS: I don't see steps in the curves though.

MR. RUBIN: Well, again I don't have the right curve here. Maybe if you give me some time, I can --

MEMBER WALLIS: No its okay, we need to go on I think.

MR. RUBIN: This again is a heat up curve not an irradiation curve. All I will say is that if you just go through the arithmetic of when one particle in 15,000 fails, what does that turn out to be in terms of --

MEMBER WALLIS: My point simply is that because the German's had some experience, it doesn't mean to say that is the experience you are going to have?

MR. RUBIN: Absolutely not. That is why we said we want to test production fuel for the GT-MHR. Whether it becomes available --

MEMBER WALLIS: It may not be so clear, the distinction between the fusion and leaky particles and porous particles and popped particles and whatever. It is all going on together.

MR. RUBIN: Let me say this. That there

are test that we don't propose to do that are characterized in --

MEMBER ROSEN: Use the microphone.

MR. RUBIN: There are tests that we don't propose to do and that is testing on individual loose particles. When you can do testing on individual failed particles, then you can get a good measure of fission product release from failed particles. It is kind of a separate effects type of a test.

What we are doing is an integrated effects test by looking at the entire pebble. But I will say this, that you will see a step change in release to birth ratio by the gas re-monitoring when a particle fails and you can actually determine how many particles have failed just based on the mathematics.

And that particle failure will dominate the releases that are being monitored. They will just by the order of magnitude, you are picking up a particle failure and then that will basically swamp the tramp uranium of the ratio. At that point you are seeing particle releases.

MR. RUBIN: I am not sure where we are here. Okay, let me just say the other thing. In addition to pushing the margins, we do want to understand whether or not the irradiation testing itself is, that has been historical used is conservative again, accelerated testing has been done as a necessity for getting results sooner.

But there are some issue whether or not that may not be conservative for some of the failure mechanisms such as chemical attack which take more time. We also think that simply by doing these kinds of tests, we will better understand the how you can do them right and how you can do them wrong and be in a better position to evaluate fuel qualifications.

CHAIRMAN KRESS: When you say chemical attack, you are not thinking of air and water ingress? You are thinking of fission palladium attack.

MR. RUBIN: Palladium attack, that kind of chemical attack. In terms of the kinds of accident testing we would now do, moving from irradiation testing to accident simulation testing that are going to be basically three areas.

Heat up testing, reactivity type events and then the chemical attack type events. Again, these would be for conditions in each category that are beyond the design basis.

So for heat up events, we would start with fuel that was irradiated beyond the design conditions and then go through a heat up that was beyond let's say the 1600 degrees C temperature criteria that is specified typically for this fuel.

For reactivity events, we do a similar thing there. Identify what would be a bounding reactivity pulse event and then run a test of that to observe fuel behavior in terms of disassociation and gross failure of the fuel. And then we would plan on doing oxidation tests on a irradiated fuel elements to understand how fuel that has been irradiated beyond its design conditions. What the oxidation effects are in terms of particle failures.

CHAIRMAN KRESS: In the models for fission product release from LWR fuel, the testing was done by heating up slowly and holding temperatures. And heating up and holding at other temperatures. And because the release was basically at the fusion process.

I envision the release from this kind of fuel being a failure of the particle process mostly. Plus some diffusion after that. That is driven by the failure of particles. It doesn't seem to me like this slow heat up and hold is an appropriate test to look at what causes the particles to fail. It seems to me like you need to model an actual set of expected temperature ramp rates in accidents.

I am just exploring what your tests might look like -- accident heat up rates?

MR. RUBIN: That comes up in the next slide actually where we want to explore whether or not the traditional testing methods for accidents, for heat up accidents is conservative. And I could just jump to that one next.

MEMBER ROSEN: You'll have to come back, I have a question on this thing.

MR. RUBIN: Okay. I can get to it in the next slide or two. But we will be testing the ramp and hold, as I refer to it, against the actual time versus temperature that you would see in a real accident to see if you see any differences in the number of particle failures you get for that.

MEMBER ROSEN: One of the things you will have to do I think is on the reactivity events, you'll have to do that test with high burn up fuel. Because you can't choose when you are going to have the super critical reactivity event. It might just decide to happen late in the life of some of the particles.

MR. RUBIN: Yes, there is a tradeoff between the level of energy that you can put into the particles late in life, versus the pre-condition of weakened fuel, you might say, later in life. Against the newer fuel that is not weakened, if you will, by irradiation. But has a higher potential for a larger energy spike in it. And so it is not clear which is the worst.

MEMBER ROSEN: You'll have to figure out what the worst case is and test it. Otherwise you will end up where we are on light water reactor fuel.

CHAIRMAN KRESS: I think you have to test both of them.

MEMBER ROSEN: Yeah, reactivity insertion accident questions about high burn up fuel.

MR. RUBIN: Yes, I would agree with you on that. That you need to do two or even three places in the burn up history of the particle.

I will go over the next slide in terms of what we will be monitoring because it's the same for irradiation pretty much. But here is where that question came up. We also want to evaluate the test methods by this test program and so we want to do it both ways on fuel that has been irradiated to beyond the design levels to go through the traditional law of rapid temperature increase and then hold at constant temperature, let's say 1600, 1700 or 1800 for hundreds of hours as opposed to going through a heat up which tracks the predicted temperature increase in the fuel in the worst case accident.

There is some evidence that in testing of AVR fuel in Germany, that there were failures seen in fuel that was tested that way with the actual time temperature approach that we are not seeing in the ramp-up and hold approach. And there is not a good explanation for that at this point. I will say that in the pre-application review from PBMR, there was a sentence in their information on qualification testing that they may do that kind of testing themselves to see whether or not there is an unknown phenomenon that makes that kind of a more precise temperature versus time more challenging at fuel than the ramp-up and hold.

And that is a good example of who is going to do this test. Are they are going to do it? Or are we going to do it. And that can come up along the way in many of these areas. We are not sure, but somebody needs to do this.

MEMBER ROSEN: The curious statement that applicant says he may do this testing. Now, how much credit do you give them for the "may"?

MR. RUBIN: Well that kind of needs to be kind of discussed. I think what happened was, we raised this issue in one of the early meetings and the put a little place holder in their submittal.

MR. FLACK: They didn't say they won't do it.

MR. RUBIN: I think we would like to see them do that. Okay, the question came up, how the heck are we going to do all of this. And in terms of the irradiation testing, we want to enter into cooperative agreements where we can. One is with DOE. DOE has this fuel development and qualification program which involves irradiation accident simulation testing.

And we have put together a document which describes how we would cooperate in sharing of data for that kind of testing. We are not yet sure whether or not DOE plans to go forward with irradiation testing given the current situation with the pull back by Exelon.

Also, we have been in discussion with the European commission. They also have an irradiation test program, an accident simulation test program with what they call the HTRF. Which is a High Temperature Reactive Fuels working group project. That calls for irradiation testing of both Pebble fuel and compacts to burn ups which far exceed the anticipated burn ups for this next generation HTGR's.

Another opportunity for obtaining data is IAEA initiated efforts to put together a new coordinated research project, Number 6 they call it. Which will pull international data on current and previous testing, irradiation testing of TRISO particle fuel as well as many other things like model development, properties for models, manufacturing expertise and the like.

We are also in the process of putting together an agreement with the Japan Atomic Energy Research Institute for obtaining information data on what they have developed on irradiation testing of fuel compacts with TRISO fuel. And there may be some basis for actual reactivity pulse testing which they have a need actually, a licensing need to do that kind of testing on their fuel. And we might want to enter into a cooperative arrangement where we get that data and also provide some fuel compacts for fuel with TRISO particles made in this country.

And also information exchanged from I-Net. And they currently have fuel qualification program that is no ongoing and we'll soon hopefully have operational data on their fuel. And we hope to obtain data from that.

So we don't see that we are going to be

paying for everything, in fact we like to get data from other sources and share in the cost. Let me quickly go over the next part, which is to develop our analytical tools. The objective here is to provide the staff with an independent capability to analyze a TRISO particle fuel performance. In both Pebble bed reactors and reactors with prismatic fuel.

We have two kind of complimentary objectives and two kinds of analysis needs. One is codes that can predict particle failure if you will that has in it many of the models for the failure mechanism that I talked about. But then there is a traditionally a second code that actually goes through and calculates the fission product transport out of the fuel element due to diffusion mechanisms from matrix material as well as from intact particles, as well as from failed particles.

And so you are looking at the need to kind of couple those two codes and those two capabilities. With the two, we would then have an independent capability to assess an applicant's calculations and to provide input to our own source term analysis for accent consequences based on the fuel fission product release from these codes.

MEMBER RANSOM: Is that an effort starting from scratch or are you building on existing?

MR. RUBIN: Same approach. I think it is in my next slide. The strategy is again to cooperative research with organizations world wide that are working on developing such codes. And there are many choices, many organizations that are doing this. We have to place our bets soon on which one we want to support.

Let me just say though that developing these tools is a challenge. If you look back at the German codes and let's say the more recently the Japanese fuel codes. They were very specific to the properties that related to the way they made the fuel and the results of the irradiation testing to bench mark those codes. And so you don't really have a code with models which have universal applicability to fuel that we made in the future. And so you need to have enough capability build into the codes to be able to predict any kind of new manufacturer given the kind of characteristics or properties that may evolve from that manufacturer. So that is a difficulty.

The property data that exists for unirradiated, and especially for unirradiated codings is meager and wide variations. And these properties play a very large role in when particle failure might be predicted. Things like creep, irradiation induced changes in dimensions of the Pyrolytic carbon layers varies tremendously. Even thermo expansion, there are large variations one would see in the literature. And so kind of get it right, you have got to get the materials data right.

We talked about the failure mechanisms. And you can have local imperfections in the silicon carbide. You can have local tearing away or debonding of let's say the outer Pyrolytic carbon layer from the silicon carbide. And so you have localized effects and that drives a need for 3-D modeling in doing these kinds of analysis.

CHAIRMAN KRESS: The 3-D modeling, where would that come in to play? Let's talk about a local defect in one of the layers. Are you talking about 3-D modeling of how the fission products move through that, or are you talking about further expansion of the failure to make it worse?

MR. RUBIN: Well I mean what you are talking about is localized stress risers ultimately. That then are going to be controlling in terms of exceeding the ultimate strength of the silicon carbide.

CHAIRMAN KRESS: But that is normally not a 3-D concept.

MR. RUBIN: Well I mean you do have an azimuthal variance. You don't have uniformed properties in all directions. It might be a localized. So typically you use a fine net element code to try.

CHAIRMAN KRESS: Normally those properties vary the radio as compared to azimuthal. In all, azimuthal directions are doing about the same.

MR. RUBIN: Well, but I mean if --

CHAIRMAN KRESS: I'll just try to figure out what actually is a 3-D. Is it a 3-D finite element model?

MR. RUBIN: 3-D finite element is different than what it is your looking at here to get those localized effects like a local layer debonding that may ultimately cause the ultimate stress to be exceeded in a silicon carbide.

CHAIRMAN KRESS: Is the idea of these finite element to actually mechanistically predict failures of fuel. As they sit there in temperature for a long time for example?

MR. RUBIN: I mean when you do a PIE and you see a failure. And you see the failure mechanism was due to let's say a crack forming in the outer layer. And then that you will see it propagate then into the silicon carbide layer. And then you basically failed the particle. How do you model that localized phenomenon of that propagation of the crack from way or into the other.

Three D modeling is typically what is used for that. If there is a little imperfection in the silicon carbide layer to cause a stress riser, it may not be uniformed around 360, but it may be a small arch where you have a notch, shall I say, so to speak in the silicon carbide and finite element techniques are useful for that.

CHAIRMAN KRESS: Other than understanding what when on, I am trying to figure out how I use that information in a severe accident or a normal operating predictive mode.

MR. RUBIN: Well those kinds of issues, I guess in my mind would be if they were to be significantly wide spread by say the reactor reload. Where you had imperfections. This kind of a code with this capability is what you would need to kind of really understand how that defect played out in terms of the failure rates.

And so it would be useful then as a tool for understanding, agreeing that yes, that was the root cause for the failures that we saw. And we now understand the corrective actions to address that. This kind of a code may not be of importance for a source term, however.

Okay and in the case of a source term you might be able to get by with a nonfinite element, two dimensional type code. And then you could variation of properties to get some statistical results in terms of number of particles that failed due to variations.

CHAIRMAN KRESS: That was what I was envisioning.

MR. RUBIN: That kind of thing. But, if you do in fact find that you are having some defects or manufactured, the only way you can actually corroborate analytically that is what was the cause is through this kind of capability. But I am not proposing that we would need three dimensional finite element codes for source term calculations.

CHAIRMAN KRESS: I think I understand now.

MR. RUBIN: I am envisioning the time where we have an operating plant and low and behold we have hard and expected fuel failures. And we start getting information from the applicants, this is what we are seeing. And this what we think was the cause in manufacture and this what we are going to do.

Okay we are going to want to do an analysis of that to see if we would predict that kind of wide spread failure do to that cause. But that capability is not needed for a source term calculation.

MEMBER WALLIS: You have described so many things that I think you are going to be under great pressures or restrict your activities. And someone is going to say, what regulatory need does this serve. And do I need to know this now. Because your scope is getting so huge. I think you are going to be under those pressures. I think that is what the gentleman is getting at here.

Do you need to do all these things in order to serve the regulatory needs?

MR. RUBIN: Let me just say that with the computing power of modern day computing the finite element basic platform for doing failure analysis is not a costly or prohibitive approach. And many of the newest codes that are being developed for a particle performance analysis are finite element codes.

As opposed to two dimensional codes. The older codes that were developed in Germany were two dimensional codes. But to go to three dimensional codes is not a big price to pay, if you will. And we are just taking advantage of the opportunity and it gives us more flexibility in how we can apply that code.

MR. FLACK: Your point is well taken. The plan itself is to get out all the issues that we have on the table. And then we have to decide at some point what it is that we really need to do, now and what other licenses can do and that sort of thing.

MEMBER SIEBER: It sounds like one you would do later.

MR. FLACK: I am sorry?

MEMBER SIEBER: This one sounds like one you would do later.

MR. RUBIN: But again if you basically going to use the three dimensional code as your platform, it is just, it is wise to go with that platform. Because that is what they are using now. It is not a big cost in terms of running the code.

MEMBER SIEBER: By the time you will need it, they will be doing something else.

MR. RUBIN: But again, the 3-D code can be used in the two dimensional analysis to do what the old two dimensional codes have been doing.

Let me just say that probably a bigger issue is the statistical variation in properties, both dimensions and material properties of particles that can when -- goes through 15,000 particles, we win predict failure of a particle that a nominal properties and dimensions. You would start to see some small number particle failures given the variations that occurred in properties and dimensions.

And the last thing is chemical attack in the news codes are putting capability through essentially reduction in the thickness of the silicon carbide to account for chemical attack.

Again, the strategy here is the same as we were looking at on irradiation testing. There is a lot of work being done internationally. INEEL has what is called PARFUME code. It is a three dimensional code that they are continuing to develop. They brought it and developed some assessments of the differences and performance of German and U.S. fuel with that. And that may be a venue for obtaining our needs.

MIT also is working on a fuel performance code. Includes modeling of chemical affects. And we have had discussions with MIT on possibly supporting the development of their code and using their code.

The European Commission as part of our HTR-F program has an element that is to develop fuel performance modeling. And we have had discussions with them about sharing in the cost and in the use of that performance code.

So we are not going to start from scratch, we are going to try to piggy back on what others are doing.

Just real quickly, I think we talked about the applications for these kinds of code. To kind of audit the applicants integrity analysis for their fuel. To assess anomalies that may be detected in fuel performance through fission product measurements of coolant activity. And also can be used as an input into the source term analysis that the NRC would like to be able to do.

As far as fuel fabrication is concerned, we don't really plan to do any fuel fabrication development work. There are plan is to learn from what others are embarking on in terms of developing understanding of fuel fabrication.

Let me just say again, that the recent studies show a large difference in fuel performance between German and U.S. fuel, a couple orders of magnitude. Analysis of that data shows that the differences in manufacture was a big driver for those differences and so the importance of the manufacturing process on fuel performance ultimately was recognized in Germany.

In fact in their manufacturing specifications, they included a fuel process specification along with the product specifications for the finished particles which were checked by QA. The difficulty is, even today, there is not a clear understanding of how a process variation effects a change in properties and how that then plays out.

So a lot of development work that is being done worldwide, it is a very hot area. Is to understand how you make good fuel that achieves the properties that you want. And are made consistent in terms of every particle coming out the same. So our interest there is to understand the important factors of the process of fuel fabrication that gave rise to good performance.

What are the important measurable product factors that need to be controlled for a good fuel performance and what are the quality control schemes that are used to maintain both process and product within the requirements.

Again, how we are going to do this is not going to do anything ourselves, but to try through cooperative agreements with the kind of the same organizations to obtain these kind of insights and information. The EC as part of the HTR-F has also a fuel fabrication technology development component. And they are going to be trying to re-establish that or establish for the first time I should say that understanding of how fabrication causes performance.

And we want the cooperative agreement to be able to share in that insight. DOE and Oakridge are also planning to develop fabrication capability in this country. And so there might be the opportunity to obtain information from that activity.

We have information exchange from INET. And they have within the last couple of years kind of walked in the foot steps of the German fuel fabrication and now become a source or a destination for others who want to learn how to make good fuel. And so we might try to obtain data from them. And Jerry as well now has fuel operating in the HTTR.

And then the pre-application reviews themselves have provided a very good source of information for what are the key factors for fuel fabrication. So we are not really talking about doing anything ourselves, but to basically learn from the work of others.

MEMBER FORD: Stuart, do we know anything at all about the quality of work done in China? When you say you are going to be doing collaborative work and nuclear data coming from INET. For instance, do we know anything at all about the quality of the data compared to that in Europe and Japan?

MR. RUBIN: I have not personally seen any of the manufacturing QC results for the fuel they have made. I have only heard antidotal stories and statements that they achieved the level after many years that they say exceeded the German quality.

In terms of particle failure rates from manufacturer. In terms of performance in reactor, we have asked for but not yet received the results of their ongoing fuel qualification testing. So that is the proof in the pudding. So I haven't gotten that yet.

We would hope to, in discussions with them, to learn about each of those aspects, the fabrication, the quality of the product, if you will. Thicknesses, densities, and things that you can measure. As well as learn how they made it in terms of the process through discussions and technical exchange.

And then follow up and to get information on their radiation experiments. But I mean that is our picture of what we haven't implemented that yet. I would say that the European Commission had a delegation that went to China about two months ago. And the topic was fuel fabrication. And the European Commission folks who were working on this element in the HTR-F wanted to pick the brains, if you will, of the Chinese fabrication folks who develop their process to kind of learn from them. And then try to go back and try to add to it in their own program. And we would like to get involved with that.

With that, I think I am pretty much -- just in terms of how we might apply this knowledge for fabrication. We think there is a potential policy decision for the Commission to make on how the Commission would regulate fuel quality and ultimately ensuring performance in a reactor. One approach is to actually put a regulatory imprint or footprint on the fuel fabrication through technical specifications.

In other words, to monitor reactor -- excuse me, coolant activity. And another is to do testing of fuel after it comes out of a reactor.

The first one is kind of an obvious one. But it is one that I think that we have not, as an agency, gotten into on light water reactors is to actually put tech specs on manufacturing processes.

But that is where the tire hits the road in terms of assuring or resulting in good performance. So we need to make that decision on whether or not we are going to do it or not. Knowing that is where quality of performance are built in. Well let's do that.

So there is a policy issuer there, we think there is an opportunity to provide input from this into fabrication process. A risk informed, I should say performance based fuel fabrication procedures, we think there will be inspectors that will go through these plans and do some inspections. And this will provide input into what they will be looking at. Perhaps training of inspectors as well.

I am just going to jump to the last slide on summary and conclusions. Just kind of recap where we think we end up with all of this. Through this plan, we think we'll develop the infrastructure, we will effectively develop the infrastructure of analytical tools and data and know how to let the staff effectively evaluate HTG-R safety performance and also commission policy decisions.

Notably on fuel performance and quality specifications and the need for that. It is going to allow us to explore the limits and understand the limits on safety performance and safety margins of

TRISO particle fuels.

It will provide the staff with the key knowledge that is needed to understand how fuel fabrication plays into fuel performance. And therefore what we need to watch and what we need to have a regulatory oversight in the fuel fabrication areas.

It does capitalize, we think, on existing national and international activities and knowledge and experience that has been developed before in design and manufacture as well as analytical methods in testing of fuels. We think that the plan focuses on the technical issues and the research issues that have been identified at the beginning of our planning activities.

We think that the cooperative research approach that is going to be a good leverage tool to get the information that less cost and the shorter time. And we think that it is also going to put us in a position to effectively reveal a COL -- come in on either PBMR or GT-MHR.

MEMBER FORD: Do you have any idea at all of how much this all costs and are orders of magnitude away from what you might reasonably expect?

MR. FLACK: Well, you took a shot at that already.

MR. RUBIN: Well, you're in charge of the dollars. The biggest component is the irradiation testing. It is very expensive to do irradiation testing. You are in to the millions of dollars per year to do irradiation testing.

That is where we think sharing costs is going to be the only viable way to implement what we have in mind. Either through partnership with the HTR-F, the European Commission, the DOE. And that will half for lessen the cost. But it is still in the millions of dollars. The cost of developing codes is not nearly as large.

Manufacturing is virtually little cost there. Because we are not going to be doing that development, fabrication technology. We just want to have access to it through cooperative agreements.

And then the fuel, accident simulation testing, that will provide perhaps a lesser order of magnitude. Let's say in the multiple hundreds of thousands of dollars to do accident simulation testing on irradiated fuel.

But the biggest cost factor is the irradiation testing. But that is really where the biggest benefits are in terms of understanding what the limits are of this fuel.

MEMBER FORD: But even with a reasonable surety of getting some collaborative work done, you are still going to have to have a big prioritization pruning exercise. Is that right?

MR. RUBIN: I think that is true.

MEMBER FORD: And therefore prioritization approaches and methodologies are going to become paramount.

MR. RUBIN: There is a limit though. If you take a look at the test reactors that are out there. Whether you put one pebble into the reactor, you put 14 in the reactor, you pay the same. You pay for a particular slot.

It almost behooves you, if you agree that you want to do irradiation testing, is to take full advantage of all of the positions that you can put fuel in there. Because the fuel you will be getting is virtually cost free to the NRC. The money is not an issue there.

CHAIRMAN KRESS: Clearly understanding the fuel for gas cooled reactors is paramount to understanding the health and safety effects. So I would put this one high on my list of things needed to be done.

MR. FLACK: As well as how much we can capitalize on using leverage.

CHAIRMAN KRESS: And that is a timing issue also. So, you if they are going ahead with it, you need to get in there.

MR. RUBIN: Yes, that is personally a concern that if we don't sign those agreements now and have something to share with them, then we loose that collaborative possibility.

MEMBER ROSEN: At the risk of being a broken record, could you go back to the slide that has purpose of the fuel research. It was like fourth or fifth slide. If you might be able to drag that one out. Well I'll tell you what it says.

MR. RUBIN: Okay.

MEMBER ROSEN: It has five bullets, the fourth one being develop independent fuels to predict fuel fission product release and TRISO particle failure for licensing basis conditions. And I think that last phrase, for licensing basis conditions is puzzling in the light of what we said and shouldn't be in there.

You need to develop independent tools to predict fuel efficient product release and TRISO particle failure, period.

MR. FLACK: It comes down to what, the frontline office is NRR. And what they will require to license a plan and what they will put down as this is what is necessary for the applicant to achieve is one thing. And we would develop the tools that would support them in independently confirming that. Back to the point of where do we draw the line on this. Is that the issue? Like what we mean by design basis?

MEMBER ROSEN: Right, it's that issue and your apparent confusion at least on this slide that I am referring to, the fourth bullet. That you are going to only understand fuel behavior up to the licensing basis. Now, I think you need, you said you want to really understand it well beyond that. So, I think you are contradicting yourself here.

MR. FLACK: It may be that --

CHAIRMAN KRESS: It may just be a wording problem.

MR. FLACK: Yes, I think it is. I think the whole point of developing infrastructure is really to understand the fuel performance.

MEMBER ROSEN: I am trying to urge you not to say okay, some arbitrary 1600 degrees we are going to stop understanding.

CHAIRMAN KRESS: They clearly aren't going to do that.

MEMBER SIEBER: But they said they wouldn't do that.

MR. RUBIN: Yeah, I think what I had there was the thought that irradiation conditions maybe up to 1250, 80,000 megawatt days per ton, fluence of 2.5 times ten to the 25th neutrons per square centimeter. But we want a code that will take it to a higher temperature, higher fluence, higher burn up than that. Well beyond that licensing basis in terms of the operating environment.

MEMBER SIEBER: Well if I recall what you said, you said you wanted to take it to failure.

MEMBER ROSEN: Right. And that is the right answer. But not what you say on the slide.

CHAIRMAN KRESS: If there are no more questions.

MEMBER WALLIS: Well, I don't know. I am still grasping. This seems to me that this is a huge program. And it looks to me that you are searching for a level of understanding which is bigger than the applicants are going to come in with. That seems to be the philosophy.

I am not sure that should be the right philosophy. You can regulate on other bases. When you actually talk about the regulatory needs, you may find that you don't need to know all this stuff. It would be very nice to know, but you may not have to do it. I think that is the only way you can prioritize this. What you really need to know in order to regulate. And it may not have to be this tremendous knowledge base, but it would be nice to have.

MEMBER FORD: Also prioritizing would be in terms of risk. You just do work at the highest risk. Do you have enough knowledge base to come to even that criteria.

MR. RUBIN: Well again, the performance of the fuel is driven by manufacturing. And we really have to understand what are the factors there, and it is driven by the environmental conditions and the accident conditions. And they all come into play.

MEMBER WALLIS: You don't have to understand it, you just have to say to the applicant, show me.

MR. RUBIN: Well, I mean, the basic assumption in this is that the applicants are not going to be pushing their fuel to failure. They have been highly resistant of pushing it well beyond the licensing basis. They'll try to get their toes wet a hundred degrees above the maximum operating temperature. Maybe a little beyond. But they don't want to go out there and see where the failure points are.

MEMBER SIEBER: The problem is, is that it is very difficult unless you have that additional data to know what the severe accident is all about.

MR. FLACK: That's right.

MEMBER SIEBER: And then how do you do the risk. How do you make determinations like should you have containment or not.

MEMBER ROSEN: I think I respectfully disagree with my colleague. In the case of a new reactor design for this country, we should go, I mean the vendor should go as far as I would go. But if they don't, then the staff should certainly go to a level of understanding that is very deep.

MEMBER WALLIS: It's very expensive.

MEMBER ROSEN: It may very well be.

MEMBER WALLIS: You can't do it.

MEMBER ROSEN: You have to put it in context of what we are thinking about doing. Licensing, perhaps a lot of these reactors for this country. If someone ever stepped up to the bar and wanted to do that.

I would prefer not to be in the circumstance that we have found ourselves in in the light water framework where we never had quite enough knowledge. We always liked to have more. Here is a chance to get out ahead of it. Let's get out ahead of it.

MEMBER WALLIS: Do you know what it costs to do the light water.

MEMBER ROSEN: I don't know what it costs to do the light water. I imagine it was a lot. I think this would be a lot too, but in context, it ought to be done.

MEMBER BONACA: For these agreements that you are trying arrange or you have already with other programs. You probably go through some kind of, I mean, are you talking together to see that there is no duplication of testing.

MR. RUBIN: Yes.

MEMBER BONACA: Are you recording these activities?

MR. RUBIN: We have had discussions with DOE. In fact, they are coming in on Friday to give us the latest assessment of what they want to get done in terms of irradiation testing and fabrication technology development.

We have a co-operative agreement written. The signing of that agreement, I think will be contingent upon whether DOE feels they want to actually do their irradiation testing in the foreseeable future or if they want to kind of defer that.

We also have had discussion this spring with the HTR-F project leaders about what they are doing. What we would like to do. And we see a kind of synergism of between the two programs. Again, the main thing they are looking at is high burn up. Which is one of the parameters on pushing the fuel to beyond the design licensing basis.

So we would like to get that data. Some of our parameters in terms of higher temperature, higher fluence, they are not covering that. So, we could pool all this, I think our costs that we would have to kick in for could be reduced. There is overlap.

In terms of mapping out the space beyond the licensing and design basis.

MEMBER BONACA: What is the manufacturing steps? You have mentioned several times the differences in performance resulting from the manufacturing steps. Is this open information that you have available? Or much of it is proprietary and you can't get your hands on it.

MR. RUBIN: The years past, there was free sharing of this kind of information, but now organizations that are doing work and spending money see the commercial applications and the profits from all this. And so, that is the one area, irradiation testing, accident condition testing, modeling, fabrication technology. And that last one is one very few people want to share.

CHAIRMAN KRESS: In view of the time, I think I am going to call a halt to these questions and ask people to come back at 1:45 p.m. And we'll start again.

(Whereupon, the foregoing matter went off the record at 12:39 p.m. and went back on the record at 1:45 p.m.)

CHAIRMAN KRESS: Let's call the meeting back to order and we'll start right in with the materials analysis I guess?

MR. FLACK: Right, that's Joe Muscara from the Division of Engineering Technology, Office of Research.

MR. MUSCARA: Thank you. As you just mentioned, I will be discussing the materials analysis portion of the research plan.

This is essentially the outline for the discussion on the materials analysis. We are looking at background and discuss some of the metals issues and research to address these issues.

Will do the same thing for graphite. Have a little bit of a discussion on international cooperation and then finally a brief summary.

As a way of background, the behavior of metallic and graphite components is a key research area to make sure they can maintain primary system integrity. The primary system integrity is essentially a major part of defense-in-depth. And we must ensure that we maintain the integrity so that the radioactivity can be contained.

In addition, the information from the materials research is needed for conducting a PRA, especially for the advanced gas cool reactors, where there is no experience with the behavior of materials and components. We would have to essentially guess at the probability of failure for these components.

And therefore we have relatively large uncertainties in the numbers that are selected. In order to reduce those uncertainties and to get better information probability of failure, we can study different degradation mechanisms and quantify these. And then be able to use this information, probalistic fracture mechanics, to calculate failure probabilities for different components under the different conditions.

Well there are a number of issues that we have uncovered with respect to metallic components. We'll list these and then discuss each one in turn.

There are issues related to the availability and applicability of national codes and standards. This is both for metals and graphite. But there is a lack of appropriate data bases for calculating fatigue, creep and creep-fatigue lifetimes.

There are issues related to the effects of impurities. In particular, things like oxygen and chloride on degradation of components in this environment.

Issues related to the aging behavior of alloys. There is a time-temperature dependence of solid state transformation that occur in these alloys. And the concurrent -- that happens.

CHAIRMAN KRESS: Are we talking about metals and metallic components that are different than we currently have in the LWRs?

MR. MUSCARA: Yes, for the high temperature gas cooled reactors, some of the metals are different because of the higher temperature requirements. Again, depending on the design. Exelon, for example, with the pebble bed -- for the pressure vessel material, they were maintaining the same material that we are using in light water reactors.

But for example, the duct pipe which transfers the hot fluid up to the power generation units, then that is a higher temperature material not used in light water reactors. And of course, turbine blade materials would be different.

So some materials are similar to light water reactors --

CHAIRMAN KRESS: So most of this is dated for the gas cooled reactors?

MR. MUSCARA: Yes, this concept is mostly on gas cooled reactors. There are a couple of issues that are also present for advanced light water reactors and I will mention those as I go along.

But, yes, most of this is based on the gas cooled reactors.

MEMBER SIEBER: It seems to me that the, in the pebble bed the piping and the turbine casings and all that are to be designed to the same specifications as the reactor vessel itself?

MR. MUSCARA: Well, yeah that is actually one of the key issues that I'll discuss.

MEMBER SIEBER: Well that way they seem to feel that they can get rid of any kind of pipe rupture. And I would scratch my head about that.

MR. MUSCARA: Yeah, I think that is both a technical and possibly a policy issue. So we need to address that.

MEMBER SIEBER: I think so to.

MR. MUSCARA: The question comes up with respect to sensitization. And of course we are going to be talking about what we call low temperature sensitization. The sensitization during operation, not necessarily during the welding of the components.

There is a potential for the degradation by carburization, decarburization and oxidation. These are particularly interesting issues because the fix to one problem may in fact generate the other problem. So there is a very close balance in managing the composition of the effluent.

CHAIRMAN KRESS: The sensitization is sensitizing the stress corrosion?

MR. MUSCARA: Precisely. It is the same

kind of sensitization we have seen for light water reactors where the plate, the chromium at the grain boundaries and then leave the materials susceptible to subsequent tracking.

Treatment of the connecting pipe as a vessel I think is an issue. And there are some inspection issues with both the High Temperature Gas Reactor and the Advanced Light Water Reactor.

CHAIRMAN KRESS: What is the implications treating that connecting pipe as a vessel? Is that excluded from arch break LOCA?

MR. MUSCARA: Correct, yes.

MEMBER FORD: Inspection of the high temperature and ALWR, that is just to serve as a point of reference for the research. And why would you expect the advanced light water reactors to show low temperature reactors? Why are we inspecting those? In that last bullet?

MR. MUSCARA: Again, of course we inspect current reactors as defense-in-depth concept. Some of the differences with the high temperature gas cooler reactors are the long times between inspections. For example, pebble bed continuous refueling. The plants have been down every six years for a short period of time for maintenance.

What that means, that the inspection intervals have to be long. And you see inspection effective in that case. The other issue that comes up is many components in advanced reactors are not excessive. For example, containing vessels.

So there is also an additional problem with accessibility. If I can't inspect important components, what good would periodic service inspections do us. So there is some issues related to those two areas.

MEMBER FORD: So that last one really refers to inspection intervals, not looking at PIE or --

MR. MUSCARA: In-service inspection for the presence of fluence.

MEMBER FORD: Okay.

CHAIRMAN KRESS: But see, the IRIS has a lifetime of 8 years for the cooler or something like that?

MR. MUSCARA: Eight. It's got all the components. but really, it's a challenging inspection problem there to address this. In the area of design codes from the telecomponents, there is a general lack of design codes and standards. We do have available ASME code case N-499, and N-201 and there is a fairly new subsection NH for application to high temperature components.

Well these codes were developed based on data from the `70s and `80s from the LMFBR area. That means a lot of the data that has gone into these codes is taken in air and/or sodium.

In addition, data from the `90s have come up with better correlations for relating creep and the creep-fatigue interaction, which is not addressed in the code.

CHAIRMAN KRESS: Do you or some of the NRC people serve on -- people putting together these coded?

MR. MUSCARA: Yes, we participate in several committees. The ASME, for example, is now beginning to think about what needs there are for the future for these advanced reactors. I have had a meeting with standards development organizations. And describing the need for codes and standards in different areas related to materials and inspection. And in fact, I was able to get some work started, which I can cover a little bit later. But right now, I think the codes and standards committees are lagging behind on doing any work in this area. And what is in place, I believe it is not appropriate for the high temperature gas cooled reactors.

MEMBER SIEBER: What pressure does the pebble bed operate at in the primary circuit? It is not real high?

MR. MUSCARA: No it is much more like the boiling water reactor.

MEMBER SIEBER: Right.

MEMBER ROSEN: It's that high?

MEMBER SIEBER: Yeah.

CHAIRMAN KRESS: The helium was not a good heat to get the heat transfer.

MEMBER SIEBER: That's sort of an advantage. Because you don't have quite the stresses in the vessels and the various compounds that you would if you were operating at perhaps double that pressure. But the temperature is way up there.

MR. MUSCARA: Yes. And a key lack within the codes is of course the inclusion of the effects of the environment in the design, both for fatigue and for creep. And the experience we have had with light water reactors tell us that the effects of environment are quite important.

You know, when we designed and built the light water reactors, we had high purity water and therefore didn't worry too much about things like parts per million of impurities. But those are the kinds of things that will really get us into trouble.

When discussing the environmental effects on fatigue, creep, and stress corrosion cracking, as I have mentioned, there is a lack of data for fatigue, for creep, and for stress corrosion cracking for evaluating the lifetime design of these components.

We know that temperature stress, strain rate, strain amplitudes and impurities such as oxygen and chloride, reduce the fatigue in creep life and increases susceptibility to stress corrosion and cracking.

In addition, you get an increase in crack growth rates due to the effects of the impurities the environment. Therefore research is needed on fatigue, creep, stress corrosion cracking and crevice corrosion cracking to take into account the effects of oxygen, chloride, temperature strain, strain rate, strain range.

The results of this research will help us to quantify and confirm if these degradation mechanisms do -- for the helium environment. And if they do play a major role, then we would have a data base for updating the current codes and standards.

MEMBER WALLIS: It seems amazing that you have to do this research?

MR. MUSCARA: Again, --

MEMBER WALLIS: -- a state-of-the-art here somehow. Why should the NRC do that?

MEMBER SIEBER: Well there isn't any art, right? In this kind of application. So somebody has to.

MEMBER WALLIS: What business do people have designing something if they don't understand fatigue, creep and --

MR. MUSCARA: This is a policy question they have sent up on to the Commission. Can we design and license these plants when these are not adequate codes for designing them. And in my view, the effects of environment are not taken into account we miscalculate.

MEMBER WALLIS: Why should NRC do it?

MR. MUSCARA: It is much like we discussed this morning, this is work that needs to be done.

MEMBER WALLIS: So it even seems worse than this morning. This fatigue, creep and corrosion cracking of materials is a very basic thing throughout the industry.

MR. MUSCARA: Yes it is. And I think when we designed the light waster reactors, it was fairly basic then also, but we accepted. For example in fatigue, data was developed on small specimens, or smooth specimens, polished surfaces tested in air. And then we found that in fact if you test the same specimen, even though it is polished and small, there are 70 times the effect of the effect of oxygen and water. So the life could be will be by a factor of 70 times different than what we designed those plants and accepted them.

So my concern is we did it then. And I am trying to make use of lessons learned from the light water reactors and bring up these issues.

MEMBER ROSEN: From a first principles basis, why should we be surprised with that result?

MR. MUSCARA: At this stage, we should not be surprised. I mean we have seen this happening with light water reactors. But the point is, that the work hasn't been done.

I have seen some work where the effects of environment were trying to be addressed, but unfortunately the most important parameters, oxygen and chloride were not included in the impurity environment. So there is some data that is limited and does not address the key parameters. So it is work that needs to be done. I think the work needs to be done and considered while we are reviewing these license applications.

MEMBER SIEBER: I think also the light water reactor data -- much lower temperature, a third of the temperature. And so the data that is available is out of range. I mean it doesn't include even the operating condition.

MR. MUSCARA: Some of the components are higher temperature. And in fact some components exhibit creep which we don't see in the light water reactor. And in creep also, there is a factor of impurities.

MEMBER SIEBER: Is there an opportunity to use codes and standards from the aircraft industry? You know jet engines operate at pretty high temperatures in the same way as combustion turbines?

MR. MUSCARA: That is true I think from a design, I think for the process, it may be quite adequate from the data point of view. I am not sure that the data is --

MEMBER SIEBER: Of course if you take a jet engine from an airplane and you look at its service life between overhauls, you couldn't afford to run a power plant like that.

MR. FLACK: But again, just to re-emphasize the fact is that the plan doesn't say that NRC will do the research. I mean we are seeking it out through international cooperations, collaborations, and industry as well as what we may have to do ourselves. So it all has to be determined.

MR. MUSCARA: But the fact is that is a key area. The data is not there, we need to get going soon to get the data. For example, we have done the research in the light water reactor area. It wasn't the industry that came up and said, you know we have an effect of the environment it was NRC work that discovered this effect.

MEMBER SIEBER: Right.

MEMBER WALLIS: This is a research plan for the NRC. This is not a research plan for industry, I take it.

MR. MUSCARA: When we developed the plan, the general philosophy was to identify key areas that needed to be addressed.

MEMBER ROSEN: And that discussion will go on between NRR and the licensees -- the applicants.

MR. FLACK: That's right.

MEMBER ROSEN: As to how it is going to get done. And if the answer comes back: NRC you do it all, then the answer is fine. We will do it all in

2090.

MEMBER SIEBER: Well either that or give us a charge card, right?

MR. FLACK: Or a containment.

MEMBER ROSEN: It's a fair question. If the industry wants the NRC to do it all, the NRC should get to define the schedule. The industry might not like the schedule.

MEMBER FORD: But just to interrupt for a minute Joe. We are all saying that and I can understand why you are all saying that. Is it a responsible position to be though? Should we not be in the position of being an informed regulator? And i.e, have the answers to a certain extent in our pocket?

It is a question. I don't know the answer to the question, is the question.

MEMBER SIEBER: I think that we are obligated to be an informed regulator. On the other hand, if you aren't informed on even a given area, you either come up with an alternative or defense-in-depth or don't approve it. And that is up to the industry to take one of those alternatives.

One way to deal with the high temperature in creep problems is to say, here is the maximum temperature that we are going to allow you to operate this at. And when the efficiency goes to pot when you do that. And they say well it is not worth building it. You know there are all kinds of decisions that can be made and I think that --

MR. MUSCARA: But even if we say that, we have to have some basis for it. For example, I don't want to base it on information we have on error data. I would like to base that decision on what happens to these components in the actual environment.

MEMBER SIEBER: I think that is true.

MEMBER WALLIS: But you could ask them to do that. Evaluating the lifetime design is the responsibility of the designer. Isn't it? Primarily, and then you have to check it.

MR. MUSCARA: We need to --

MEMBER WALLIS: We happen to have the primary responsibility.

MR. MUSCARA: And the contention these days is that helium is an earth and it is pure, therefore data in air or helium is acceptable and adequate. Our experience tells us that it might not be the case. So some of this research may fall into an area that we call anticipatory research. If the plan is designed and built, I don't expect a problem the first year. But I might expect it after ten years.

MEMBER SIEBER: It's as pure as primary grade water.

MR. MUSCARA: Right, that's the point. It is pure -- earth quotation marks. We have three parts per million oxygen in the high temperature gas cooled environment.

MEMBER SIEBER: I imagine in these compressors and turbines you have to have some kind of lubrication which introduces. That is a major source of all these impurities. Because there are bearings in there that are usually pretty high speed devices.

MR. MUSCARA: There is, at least for the pebble bed, there's a purification system. But when I've looked at the information from the AVR, what goes into the system comes back out. With respect to oxygen for example, it comes out at less than a part per million oxygen. But it goes in at 3 parts per million. So during the cycle it picks up oxygen enough to cause the degradation of materials.

MEMBER SIEBER: And everything ahead of the purification unit, you know up stream, is exposed to the three parts per million.

MR. MUSCARA: Right. So the connecting

pipe is an issue. What happens that these high temperature gas cooled reactors, the connecting pipe has been designed, fabricated and inspected to the same rules as a vessel. So the contention is that the pipe, therefore is a vessel. And we consider a vessel, while doing that, then there is no double ended break as a design basis.

And therefore there are no mitigating systems incorporated into the design. Now, in a pipe as a vessel, it is not really realistic. Even though the pipe is built constructed, and inspected same as vessel, because of the diameter, the vessel itself is much, much thicker for the same working pressure than the pipe. So should a degradation mechanism occur in the pipe, expected or unexpected, it goes through the walls relatively quickly.

And therefore even a vessel, except for some recent experience, you don't expect degradation mechanism go through the vessel in short periods of time have a chance to be -- by inspection, etc.

So I think it is quite a major difference between the pipe and the vessel. You can inspect it the same way, we can build it the same way, but it is much thinner. That is a fact, if you want to build this thing six inches thick, then fine. Then they can call it a vessel. But it is not, it is less than two inches thick, it is very much like --

MEMBER ROSEN: Aren't current day piping, primary piping designed, fabricated and inspected to the same rules as the RPV?

MR. MUSCARA: Precisely.

MEMBER ROSEN: So when we don't allow that in LWR, so what changed is what I am asking?

MR. MUSCARA: Right, we have had the contention from the industry that they are built that way. And therefore the probability of failure is very low. And I am saying wait a minute. What about all the experience? These pipes do crack. They have cracked.

MEMBER ROSEN: But there arguments just saying that we are designing and fabricating and inspecting the same rules as the RPV, therefore, that we don't have to do anything different, it doesn't hold water on the surface. Because that is what we are doing already for light water reactors and we do take double ended breaks.

MR. MUSCARA: It is very much the same process for design, fabricating, and inspecting you know the primary system components.

MEMBER SIEBER: But the piping code is

different than the pressure vessel codes.

MR. MUSCARA: The design.

MEMBER SIEBER: So it is not exactly the same. There are some things that are different, but you are right. The smaller the diameter of the pipe, the thinner the wall could be. Look at the steam generator tube, it is very thin. And you can crack through one of them pretty fast.

MR. MUSCARA: -- we are not really planning necessarily any research on this, but we will be making use of the research in the other areas to try and determine what is the potential, what's the probability of failure in this pipe. So if we bring it up as an issue, and the research we will be conducting on fatigue and creep and environmental effects, should apply to the analysis of this pipe, how clever is it that this thing is not that, the probability is very, very low.

MEMBER FORD: So, I am just trying to follow up on the decision that came earlier and that statement you just made. So the objective of this and the other work is to come up with what do we know currently and what is necessary to be done in order to find the probability of failure of the component. That would then lead into a higher level risk informed basis, the probability of our CDF or LERF appropriate higher level safety might actually cost. Is that the reason?

MEMBER SIEBER: Well I looked at it a little bit differently. A licensee is going to come in and they are going to make an assertion. And the staff is going to ask the licensee, prove to me that your assertion is correct. And the staff has to have enough data and knowledge to be able to make that judgement.

And so, you end up with both the industry, the vendors doing some work to assert their end of the argument. Staff has got to be knowledgeable enough and have at its own command, sufficient data and experience to say you are right or you are wrong. And that is how I see this coming out.

MR. FLACK: Exactly. And that could end up being the difference between one kind of accident versus another kind of accident. And what you have to design the rest of the facility to withstand.

MEMBER FORD: But from your research, is to tell the licensee, prove to me the probability of the failure of this component by whatever mechanism is less than such and such. Is that the --

MR. MUSCARA: In my mind, that is a key

aspect also because both the design and the licensing these plans is moving more and more towards risk informed and risk based. And you need to have reasonably data to conduct these evaluations.

And since there is a lack of experience with these materials and components, we would have to predict it through some probabilistic failure mechanics. To do that you must identify degradation mechanisms, initiation times, the growth rates and so on.

MEMBER SIEBER: That's right, and the output is going to be a distribution.

MR. MUSCARA: Yes.

MEMBER SIEBER: So you can define the uncertainty and all of these get factored into this grand equation that says here is the risk of this facility.

MEMBER FORD: Yes, but the proof of the pudding, that licensee can maintain that low level of risk. That is his responsibility. And you have got to be in the position of being an informed regulator to understand that he is not pulling the wool over your eyes.

MEMBER SIEBER: Well it goes beyond that a little bit. The American people look to the agency to keep them safe within the parameters and the safety goals that they have set.

So if one of these plants goes down the tubes, licensee of course will feel some financial heat and regulatory heat. But the agency itself will feel the ire of the population whom we are sworn to protect. So it goes both ways.

MR. MUSCARA: So I think with the connecting pipe issue, essentially because it is designed as a vessel, doesn't really make much sense, number one. Number two, if you are going to design it without assuming double-ended break, you have to show that probability failure is very, very, very small. And I don't think you can do that without the information that we are hoping we can generate.

MEMBER ROSEN: Where does leak-before-break come into this discussion or doesn't it?

MR. MUSCARA: I hadn't planned on discussing it.

MEMBER ROSEN: Well, isn't it part of the discussion on this connecting pipe? If you have to assume that the pipe is a pipe, not a vessel, then can you assume that in the size range that that is going to be used, that the pipe is likely to leak in a detectable way before it breaks? And if you assume that, which I think they might justifiably try to argue. What degree of inspection would we require for leak-before-break in order to limit the break size. Maybe some pipes could be excluded as there is now being discussed in light water reactor family. While others can't.

MR. MUSCARA: Right. In general, we look at is there a potential for degradation of mechanism before we allow the leak-before-break. Because of potential for degradation mechanism, we don't allow it. And in this case, I don't see the data that is showing us, that for example, 800 age, is not susceptible to degradation in the impurity requirement of the helium gas.

MEMBER ROSEN: That is the answer I expected you to give. So we have to show that there is no degradation mechanism. When we are dealing with high temperature piping for which there is no experience it can't show.

MR. MUSCARA: And the -- light water reactor.

MEMBER ROSEN: Sure, and you have enumerated a lot of potential ones.

MEMBER BONACA: One thing that I wanted to point out. You say the corrosion in the lined base is limited in the system as incorporated. So the cracking occurs in the welds anyway irrespective of the way you build this pipe. How can the contention be made. I mean still, you have a concern with cracking through the weld, right?

MR. MUSCARA: Right. And that of course that's been the issue of sensitization over the piping in high residual stresses in that zone. With a different material, it may be more sensitized in the welding. But the other effects may be there during the operation.

MEMBER BONACA: All right, so still, even if you had capability of a vessel, that is an issue of how you put together this components in a way that you would not have potentially a break into the welds.

MEMBER ROSEN: These pipes are cooling down from that to ambient temperature from much higher temperatures than they are typically in light water reactors. I mean they go to operating temperature and when you cool them down, they come to ambient temperatures. A much bigger temperature swing much higher fatigue line.

MR. MUSCARA: Yes, depending on the design and where the insulation is placed. In the one case, the insulation is inside the pipe. In other cases it is outside the pipe. So if it is outside the pipe, you do get some bigger --.

MEMBER ROSEN: Insulation inside the pipe?

MR. MUSCARA: Yes. I think the pebble bed had their insulation jackets inside the duct pipe. In other design, insulation is on the outside. I may get the two mixed up, the GA versus --

MEMBER SIEBER: I think one of the problems was leak-before-break in a gas reactor is your ability to detect the leak. In a water reactor there is a puddle on the floor. Or humidity in the room, but here all you have is your voice gets a little higher when you go into the enclosure.

CHAIRMAN KRESS: There's a possibility of casing emissions that you can hear.

MEMBER SIEBER: Possibility.

CHAIRMAN KRESS: Well they --

MEMBER SIEBER: Some people claim that really works as well.

MR. MUSCARA: In the area of carburization, decarburization and oxidation, these phenomena are dependent on the composition of the coolant. And of course the presence of graphite particles.

Carburization in ferretic steels will lead to a hard brittle surface where cementite is formed at the surface.

For austenitics we would get carbide, chromium carbide formation at the expense of depleting the chromium. So you could leave the surface of the stainless susceptible to cracking.

Decarburization on the other hand takes the carbon away from the materials. So it leaves a softer surface layer and reduced fatigue and creep swing.

So we would need to study these phenomena as a function of time, temperature and in helium gas with impurities including the oxygen. One would conduct metallographic studies to determine whether these reactions have taken place. And also mechanical testing to determine the degree to which the strength has been reduced.

And your objective with research of course would be to characterize and bound the conditions under which the phenomena occur. As I mentioned a little bit earlier, this is going to be a very close balance between being a reducing atmosphere and an oxidizing atmosphere.

For example, I asked a question both in China and Japan about had they thought about carburization in their high temperature helium reactors. And the response from Japan, was yes they had. And in fact, they inject a little oxygen to maintain an oxidizing atmosphere to avoid carburization. Which is great for carburization, but now you are leaving susceptible to corrosion and stress corrosion cracking.

So with the experience with light water reactors and steam generators, there has been a very fine balance there also. Anytime you solve the problems with steam generators, we create another corrosion problem.

And so the conditions under which these things happen haven't really been defined very well. And I think part of the objectives we are trying find these conditions to know when to expect carburization, Decarburization and oxidation.

MEMBER ROSEN: How does decarburization proceed?

MR. MUSCARA: Decarburization? Just the activity of the carbon and the gas versus the carbon in the steel. It is lower in the gas, so that carbon diffuses out of the steel into the gas. And leaves a very soft material, very much like an iron instead of a steel.

MEMBER SIEBER: But that's a surface effect, is it not, pretty much?

MR. MUSCARA: Yes. Those would be surface effects. And what would happen because of the different properties in the surface layer, both the strength and thermal, that during operation you create stresses in the newer surface area. You could initiate cracking and then of course propagating a little bit different and a lot easier.

MEMBER SIEBER: Okay, thank you.

MR. MUSCARA: Well the issue of aging behavior and sensitization of austenitic steels, of course we do know that we get aging of casting the steel. So it does occur in austenitic materials. And some of these high temperature materials, in fact will develop for stability a temperature. But again, it needs to be shown that the materials and the condition of interest are stable. They are not -- taking place. Producing materials that were brittle, the component.

Of course that is the aging. The sensitization we are all familiar with leaves the materials susceptible to stress corrosion cracking. And the sensitization of interest here is not necessarily from the welding. We know enough about that now. But from the actual operating temperature.

The issue came up for light water reactors back in the early `80s. And some heats and materials were more susceptible to low temperature sensitization, you know from a thermodynamics point of view, look at the stability diagrams, not supposed to happen in those temperatures. But given time, we found that you do get low temperature sensitization.

And that is much more insidious because it would affect the entire surface, not just the material at the grain boundaries necessarily.

What we found for light water reactor was that generally we took about 40 to 100 years for different heats to exhibit low temperatures sensitization. So for the light water reactor, we decided, this is really not a key issue. It happens, but not in the lifetime of the plant. So with the elevated temperatures of the gas cooled reactors, small differences in temperatures, it is like rhythm.

So, even ten degrees increase in temperature could mean a good substantial reduction in the timed desensitization. So that is an issue that needs to be looked at to determine whether the materials were sensitized, therefore, again rendering them susceptible in the environment.

We would look at materials both in the as-received and the welded conditions. Again, we would conduct mechanical and microscopic studies. We would like to quantify the time and temperature for different levels of sensitization and aging, you know to determine whether it is a reasonable thing to expect during the lifetime of the plan.

And if it is of concern, of course we would have a data base for evaluating the degree of the concern and for improving codes and standards.

Well we have talked about a number of different degradation mechanisms. And it seems to me that there is an opportunity to at least evaluate some of these things by making use of components removed from the one reactor that had 23 or so years of experience, from the AVR.

Components of interest of course would be those components where we have the operating history. We need to know the temperatures and the loading on these components. So that we could determine based on design codes and standards, how much life was used up. And then by conducting research and testing, we can determine whether those expectations were real or not.

So we could determine whether some degradation mechanisms have occurred after 23 years by just looking at the metallographic structure of the components. But beyond that, we can run mechanical tests, a fatigue test and creep test. And measure what life is remaining in this component. Therefore, we get to know what was used up and see if the corresponds to the design codes.

MEMBER SIEBER: It seems to me that Fort Saint Vrain operated at much lower temperatures than these advanced reactors.

MR. MUSCARA: Than AVR?

MEMBER SIEBER: Yes, have we learned anything from Fort Sain Vraian?

MR. MUSCARA: I am not sure about any tests that were done.

MEMBER SIEBER: From a materials standpoint?

MR. MUSCARA: One of the things we learned was that you do pick up things like chloride from the graphite itself that cause stress corrosion cracking on those components. They did experience SCC from the chloride. Of course they had problems with the water ingress and the problems with that.

But with respect to the environment, the small amounts of chloride that essentially leak gas from the graphite cause the cracking in their components.

MEMBER SIEBER: Now you would get that in a pebble bed from the graphite balls that are non-fuel balls?

MR. MUSCARA: Yes.

MEMBER SIEBER: I would presume.

MR. MUSCARA: Yeah.

MEMBER SIEBER: Okay.

MR. MUSCARA: For the issue of the in-service inspection and continuous monitoring, as I mentioned, there are long operating periods between the short duration outages. So the ISI intervals may be long. And the amount of inspections limited mostly due to accessibility problems. So we need to re-evaluate the effectiveness of different ISI programs. Taking into account both the reliability of the inspection, but also the degradation mechanisms that are possible. And taking into account those components that cannot be inspected by in-service inspection.

MEMBER SIEBER: I would think though, early on the designer along with some help from the staff would try to make as much of the plant inspectable as they could as opposed to having ISI come along as an afterthought. And you can't get into the curves and you have a lot of partials and things like that.

MR. MUSCARA: That is quite a reasonable expectation. And in fact, the ASME code requires the components to be constructed in such a way that they are accessible for inspection.

MEMBER SIEBER: But they aren't.

MR. MUSCARA: But they aren't. So they come in and ask for relief.

MEMBER SIEBER: Right.

MR. MUSCARA: And in fact when I brought this question up with the Exelon pebble bed, so it has to be realized there are some important components that can't be inspected. We plan on requesting --

MEMBER SIEBER: Relief.

MR. MUSCARA: Relief. Not at the design stage. I mean this is the time when you try to make components inspectable. You don't come in and ask for relief because we can't inspect it even before you design it.

MEMBER SIEBER: Because you don't feel like designing it. You know, inspectability is built in.

MR. MUSCARA: So it violates, already, the guidance of the code.

MEMBER SIEBER: Well I would think that

would be an important consideration up front. You know, when somebody comes in with a design concept that should be one of the rules. It ought to be inspectable. It ought to meet the code.

MR. MUSCARA: Yeah, I think from a technical point of view and policy point of view, one of the things that we could be considering is that given in-service inspection can be conducted infrequently, when components are not available, should we require continuous online monitoring. And that is one of the research areas also that we have planned.

The evaluating in-service inspection programs themselves, we would plan on conducting work using our risk-informed inspection guidelines to determine how important it is to inspect components. And for that results in an ineffective inspection, then we need to consider the continuous online monitoring.

The work on continuous online monitoring has been conducted for light water reactors. And we have developed a technique acoustic emission monitoring. For both obtaining the initiation of cracking and for following the crack severity as the plant is operating.

MEMBER SIEBER: I have a question about that particularly as applied to a gas reactor. Acoustic monitoring, listens for basically sound effects from the development of cracks in piping and so forth. For example, frequently it is used when you do hydrostatic tests as a way to determine whether you are leaking or not.

On the other hand, if I have a high speed compressor in a turbine operating, is that going to swamp out your ability to hear these things. Or can you discriminate among the sounds well enough to differentiate between the actions of the stress from the mechanical equipment that is out there running?

MR. MUSCARA: In fact, we had about a ten year research program back in the late 80s and mid 90s.

MEMBER SIEBER: I remember that.

MR. MUSCARA: -- in this area. And one of the key issues is if I have acoustic emissions is that because of cracking or some other noise source. You can't really mix the two.

So we did quite a bit of work in developing methods for discriminating noise from crack growth noise. And after many years of work, we found a very simple idea that happened to work or not even looking for this. But we conducted the laboratory work and then were ready to conduct work at an intermediate scale vessel at MPA Stuttgart. And then eventually monitored an actually plant.

Some of the work we have conducted was how do the transducers behave under the high temperature/high humidity environment. How does the coupling behave. Well we decided eventually that we needed to use a wave guide to get away from the problems of having the transducer directly on to the hot surface. So if the wave guide is coupled to the vessel or a pipe, and it is moved out of the hot area. The transducer then is coupled to the wave guide. And we conducted some tests using this technique for getting away from the temperature.

MEMBER SIEBER: The guide did the discrimination?

MR. MUSCARA: What we found was the guide did the discrimination. The sharp rise time signal from the cracks produces three mode converted sound waves. And so they are depending on the length of the wave guide, they are spaced at specific distances apart. And the white noise from other noise sources doesn't behave that way. So what we found was almost a 100% reliability, in discriminating cracking from noises, just through the mode converter sound wave in the wave guide.

MEMBER SIEBER: That is interesting. I remember the issue coming up and the problem with it because we had tried a couple simple things ourselves. But then I never followed up to find out how the problem was solved.

MR. MUSCARA: We had up to this point, we had developed euronetworks for discriminating noise from crack growth noise. And that was about 80 - 85% effective. But the wave guide was much simpler and much more effective.

MEMBER SIEBER: Cheap.

MR. MUSCARA: Cheap. So we have done this work for light water reactors and as I mentioned, with a large scale testing in and fact we monitored the Limerick reactor on a stress corrosion cracking at a nozzle. And what we found was that the acoustic emission could detect the cracking. Could characterize its growth. It could match the UT results.

Unfortunately after to one cycle, we monitored for two cycles. After one cycle the cracks stopped, you ran into a compressor stress field. And the crack stopped and the utility never removed the pipe for severe finding validation. But we did measure the crack growth and had estimated its degree of cracking.

MEMBER SIEBER: Well it would seem to me as a regulatory alternative, for example, if a licensee wanted to consider the coolant piping the same as the vessel, that this would be an acceptable alternative that you would require provided there is a good technical basis would show you that it worked. Because it doesn't sound too expensive.

MR. MUSCARA: I think the basic work has been done. It has been shown that it works in the light water reactor environment. What we would need to do with the gas cooler reactors to ensure that under the noise conditions of the --

MEMBER SIEBER: Well the spectrum is going to be different.

MR. MUSCARA: It is going to be different. And also the mechanisms. Of course, we have creep to worry about. You know, we have looked at fatigue and stress corrosion cracking for light water reactors. But of course we never looked at creep.

So there would be some additional work remaining to validate this technology for gas cooled reactors. But I think it is already a long way there.

MEMBER SIEBER: Yeah but you have a material problem just in the wave guide. Because it is on a much hotter surface than in a water reactor. I am sure you could, that one is easily solved compared with some others.

MR. MUSCARA: I think so.

MEMBER SIEBER: Well thank you, I appreciate that. That brings be closer to being up to speed.

MR. MUSCARA: Well I think to deal with the metals issues, there maybe some others, but I thought they were some of the key issues that we were considering. Moving on to the graphite.

Similarly there is a lack of data on high levels of irradiation for current graphites. There is data on the older graphites. But as we learn that the properties of graphite are very much dependent on how it was manufactured from the raw materials. Unfortunately, the raw material sources from the old graphite is gone. The mines have been closed.

And also some of the vendors. I think most of the vendors, the original vendors are gone. So the manufacturing processes in the raw materials for the new graphites would be different. Even though we striving, the industry is striving to make the graphite the same way they have done in the past. Where there is data.

MEMBER SIEBER: But the old reactors, like the N reactor, had these huge blocks of graphite with holes in them. And that to me would be a lot different than the codings on these particles or the graphite balls. Because they are discharged on a regular basis. And don't exhibit that long term distortion and growth that you would get out of a massive block of carbon.

CHAIRMAN KRESS: Yeah, but the reflector --

MR. MUSCARA: Of course I am not addressing the fuel portion. This is just the reflector, structural components --

MEMBER SIEBER: Yeah, the reflector is bigger blocks, okay. Thank you.

MR. MUSCARA: But in addition, the graphite, the pebbles do we have a graphite layer?

CHAIRMAN KRESS: They have a graphite coating.

MEMBER SIEBER: Yes they do.

MR. MUSCARA: Right. That layer also is not graphitized at the high temperatures that the rest of the graphite is. It is a much lower temperature.

And so it behaves differently than the reflector graphite.

CHAIRMAN KRESS: The matrix inside, could it be called a graphite or is it more just a carbon. I don't know if I would even call that --

MR. MUSCARA: Both graphite and carbon.

MR. CARLSON: It is sometimes called a "graphitic material."

CHAIRMAN KRESS: Graphitic material.

MR. MUSCARA: There is also a lack of predictive capability for the irradiated graphite properties from the unirradiated prosperities. Of course, I'm sure you follow the light water reactor work. For many years we have been working trying to correlate embrittlement in pressure vessel steels, and there is still work to be done there, but in the graphite we just have absolutely no work that has gone on to try and relate those properties.

In my mind that is an issue because as I mentioned, the graphite properties will vary. The irradiated properties based on the raw material properties. And the raw material properties vary as a function of the source and manufacturing process.

CHAIRMAN KRESS: Now in the case of the reflector, what are you worried about? It is not a structural --

MEMBER SIEBER: It doesn't carry any load.

MR. MUSCARA: I guess I have a couple of view graphs that will address that.

CHAIRMAN KRESS: Okay.

MEMBER SIEBER: Yeah I would think that it could just grow anyway you wanted them. All you would have to do is provide enough space.

CHAIRMAN KRESS: I would think in the prismatic concept you have a problem.

MR. MUSCARA: But the point was, that every time a new graphite comes a long, then you would need to have a comprehensive irradiation program because you know it is a little bit different, it will behave differently. And my thought is that we need to have a methodology that allows us to go from the unirradiated properties to the irradiated properties. No work that's gone on to try to relate those properties. In my mind, that's an issue because as I mentioned, the graphite properties will vary. The irradiated properties, based on the raw material properties and the raw material properties vary as a function of the source and the manufacturing process.

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And my thought is that we need to have a methodology that allows us to go from the unirradiated properties to the irradiated properties.

CHAIRMAN KRESS: You need a theory mechanism.

MR. MUSCARA: Mechanism and a lot of experimental --

CHAIRMAN KRESS: A lot of experimental to back it up.

MR. MUSCARA: There's also lack of oxidation, kinetics data for graphite, again, for the newer graphites.

The pebble bed reactor folks have suggested that they would use the graphite properties from the experience with the British reactors, with the sleeve reactor. Well, that's a much thinner component. It's manufactured differently. So it's not clear that the properties from the sleeve graphite in the experience pertains to the large block graphite used for the high temperature gas cool reactors.

And again, there's a lack of codes and standards for nuclear grade graphite. Very surprising for me, there's not a material specification standard for nuclear grade graphite. So we can -- the designers effectively use the information and the properties given to them by the manufacturer and they're fairly comfortable with this in that they make use of the design, that they did in the design.

My concern is, for example, if I have a graphite that is for some reason a very low tensile strength, the component is going to be thicker than it would normally be, so the designer feels he's addressed his problem. It's thicker, lower strength. We're fine. But there's some underlying reasons why this graphite is set for strength. Maybe it's successive cracking or porosity which although the component is designed thicker, those cracks will propagate during operation and cause failure of the graphite. So it's not enough to just use the properties from the particular batch of graphite. We must have certain minimum requirements for the graphite.

In addition, we need to have requirements for things like impurities which can leave the graphite and cause degradation of other components.

MEMBER SIEBER: In the reflector though, let's say the graphite cracks and you know, it's just in a can, right? And so why do you care, other than somebody else has to go and replace them.

MR. MUSCARA: Some of these components, the control rods are inside the graphite log, so that we have distortion. Then you have a problem with inserting the control rods.

MEMBER SIEBER: Right. So you make the channel bigger, right? Well, seismic is an issue if they really shift during a seismic event and so on.

MR. MUSCARA: It provides the structural integrity for the core in the core geometry.

I think we may have mentioned some of these items already, but the current data is for the old graphites. Irradiation degrades the physical thermal mechanical properties of the graphite. These changes can cause stresses during operation and loss of integrity.

The strength of graphite initially increases with irradiation dose and then at higher level it begins to decrease.

The dimensional changes that initially graphite begins to shrink and then with increasing radiation it begins to swell. And then, of course, beyond the turn around, the graphite loses an entire structural integrity. It essentially falls apart.

As we mentioned, the loss the structural integrity, the loss of core geometry and potential problems with insertion of control rods. So we would need to study the changes that undergo in the graphite as a function of the levels of radiation and temperature.

I guess with respect to temperature, I want to mention that if we irradiate these materials at higher temperature, that's not necessarily a conservative direction to go into. For example, we discussed a little this morning getting margined by doing higher temperature exposures of the fuel. At higher temperatures, you get some annealing, so going up to a higher temperature to study radiation effects is not necessarily a prudent thing to do. I mean we need to go there if we experience those temperatures, but irradiation at lower temperature sometimes can be more detrimental because it does not anneal out the damaging effect from the irradiation.

MEMBER SIEBER: I thought in decades ago that was how they would run a graphite reactor at very high temperature for a while to try to recover the graphite physical properties and basic dimension.

MR. MUSCARA: You can anneal out some of the irradiation and also having a little creep, it helps at the beginning that you are relieving the stresses. Of course, you're getting too much creep with the material starts to flow. It's not a good thing.

MEMBER SIEBER: On the other hand, the net effect of that is to make it more brittle and less weaker?

MR. MUSCARA: With the irradiation?

MEMBER SIEBER: With the annealing? Or multiple annealings?

MR. MUSCARA: On the graphite?

MEMBER SIEBER: Yes.

(Pause.)

MR. MUSCARA: Anyway, as far as research

in the area, we would intend on reviewing available high dose irradiation data. Some data has been taken, for example, at Oak Ridge, under a DOE program. That data was never analyzed because they ran out of funds. We would hope they would have access to the data to analyze it.

We would conduct irradiation tests on test reactors, high flux test reactors, different temperatures, different irradiation exposures. And we would conduct microstructural evaluations, dimensional, mechanical, thermal and physical property measurements, both before and after the irradiation.

As mentioned earlier, this kind of work is very, very expensive and clearly it would also be depending on international cooperation to get some of this information.

Again, I brought up the issue the need to have correlations between the unirradiated and the irradiated properties. These properties depend strongly on the raw materials and the manufacturing process. Some data is available from old graphites, but no data on the new graphites.

In the conducting research, what I would hope is that we could more or less piggyback on some other work that's going on. I can get to this a little bit later, but the European Community is already planning on conducting some extensive irradiation testing of five current day graphites and I would hope that we could conduct some parametric studies along with those studies to evaluate some of the changes in the raw material properties and how this affects the irradiation.

So there's work that's going on, but the work could be augmented to try and get at not only, for this particular graphite, this is how it responds, but trying to get some correlations for the important parameters to predict how those parameters affect the irradiation behavior.

(Pause.)

Again, this will be the kinds of studies we would conduct. I think I've mentioned most of these already. Temperature irradiation levels, raw materials makes a big difference. And processing parameters, they manifest themselves into the properties of the as-received graphites. There are many different ways of getting to the same properties. So just looking at processing parameters might not give us the final result, but we need to keep in mind when we develop a matrix of tests what are the important processing parameters that affect the raw material properties. And they make sure that those things are incorporated.

There are a lot of different parameters, both processing and initial properties that need to be looked at and we need to do a careful job of selecting and evaluating which parameters to use for studies. To do this, my thought was we get together a group of experts and discuss what are the potential most important properties that might affect the irradiation.

So there would be several workshops held before one would even develop a test matrix for this kind of work.

In addition, I'll mention it later also, but we have acquired a graphite expert for our branch who will be working in this area and he has an assignment, about a 3-month assignment in the U.K. to take advantage of the experience and knowledge that's been gained there and also make use of the experts that are available to start developing some of these test matrices.

CHAIRMAN KRESS: Do you think three months is enough time for him to --

MR. MUSCARA: Probably not, but at this point I thought that's what we could afford. It would be a good first try.

CHAIRMAN KRESS: When you run these tests on graphite, irradiating and see what effect it has on the properties, do you need large specimens or can you do this with small?

MR. MUSCARA: That is an important question. That's something that needs to be decided. My view is that the property will change through the thickness -- the raw material properties, therefore the irradiation properties. And we need to know what those properties are as a function of thickness. So I think we need to be very careful about what select and as a minimum have samples from the surface and some intermediate locations going through the center of the component.

MEMBER SIEBER: Well, the fluence varies through the ball section --

MR. MUSCARA: Sure.

MEMBER SIEBER: So the properties will vary at a right angle.

MR. MUSCARA: The irradiated properties. But even the raw material properties. The chemistry will change through the thickness, the density, the porosity --

CHAIRMAN KRESS: Yes, that will wear more than fluence because you can take care of the fluence otherwise.

MEMBER SIEBER: So you can calculate it out.

MR. MUSCARA: Right.

MEMBER SIEBER: Would the ultimate outcome of this kind of work result in a standard? I would think that would be a good way to codify how you're going to use it and what properties it ought to have. Or would you have it as a reg. guide or --

MR. MUSCARA: Yeah, I think the effects of irradiation, how it affects the properties, needs to become part of a standard, a design standard.

MEMBER SIEBER: Right. I agree. Well, I was thinking in terms of a national standard like ANS or somebody like that.

MR. MUSCARA: Well, oxidation kinetics so it's another area where there's a lack of data. This information is needed for evaluating the heat generation, the structural integrity, and core geometry during normal operating and accident conditions. The air ingress, of course, would lead to corrosion and oxidation of graphite. It's an exothermic reaction so we need to know how much heat is generated and of particular importance during an accident condition.

There's a loss of material surface, so the structural integrity could be impaired. There's a reduction of fractured toughness and in strength of the graphite with the oxidation and changes in thermal conductivity. So all of these parameters are important for safety review and evaluation.

CHAIRMAN KRESS: Now are you interested in the cases where you have an air ingression accident that could lead to rapid combustion or rapid -- or are you interested in low levels of contamination of oxygen and helium? This long term degradation effect.

MR. MUSCARA: We're considering both. So one of the bullets here has to do with the amount of oxidant in the atmosphere. So for as low air ingress it would be one level; for break would have much more oxidants available to oxidize the graphite.

We're interested also in different kinds of graphites. The graphite, you say the pebble graphite which has not been graphitized at high temperature will have a different rate of oxidation. We're interested in evaluating the oxidation rate of graphite dust. The dust will deposit on surfaces, but if it's, you know, we have an accident now, it's the graphite dust in a given surface, it oxidizes faster.

Heat generation. We need to know how it affects the particular component.

CHAIRMAN KRESS: Now when people do these kinds of tests usually they do them with small specimens. Now the questions comes up on the effects of an air ingression accident. Will the graphite itself burn or have a sustained oxidation process? And that generally is a geometry problem and how much heat are you generating and how can it dissipate in various directions and how much oxygen you can get there to produce the combustion.

Do you have plans for some sort of look at that question, the combustion of large chunks of graphite?

MR. MUSCARA: It's a question, but I don't think we've defined how to go about conducting those tests.

CHAIRMAN KRESS: But that's not what you're talking about here. This is something else.

MR. MUSCARA: I think it's both. I mean we need to know from the dust to the large component, how that affects the rates in carrying away the heat if it's a large component. So we would measure the heat generation and the oxidation rates, both.

Well, we talked about the variability of large block graphite and want to use information from thin section graphite. Again, the designers, because of lack of data, where hoping they could use data from the sleeve graphite, but that's a lot thinner and it's not clear that's applicable. So we need to conduct more in this area to determine the differences in the graphite through the thickness, both in properties, chemistry, things like porosity, distribution, and numbers.

We're not planning on irradiation work as a function of this variation in block thickness, but if we evaluate the changes in properties in the raw graphite, and if those changes are considerable, we have to be able to estimate whether irradiated properties would respond also to a large degree.

CHAIRMAN KRESS: What I envisioned earlier when I thought to ask you had to use big specimens to do the testing. I thought maybe you could use the big specimens that were sectioned right and look at their property variations and put each of those sections in the same fluence area and that should test a lot of small specimens representing one big one.

MR. MUSCARA: Again, we're going to take advantage of work going on in Europe and Japan in this area. They are planning work both in oxidation and irradiation. I'm not sure how the tests are really being set up, but that's why I suggest we have an expert group meeting to define those tests.

CHAIRMAN KRESS: That's probably a good way.

MR. MUSCARA: Well, the lack of codes and standards in nuclear grade graphite, again, I think most of these things I've mentioned with respect to the issues, but there is a lack of design codes for taking to a concrete fatigue strength fracture toughness. We need material specification that established the minimum requirements for mechanical, physical, and chemical. We would need to limit elements that may be detrimental to the irradiation properties, or elements that can cause degradation of other materials. For example, the chloride that we had experience with.

With respect to the specification, I've contacted ASTM staff to discuss whether there's a potential for them to develop in nuclear grade specification for graphite. And they agreed that they should and can develop such a standard and their activities are already in place to develop a nuclear grade graphite specification. We're supporting a little work on that at Oak Ridge National Laboratory.

We're providing one staff person who's an expert in graphite participating the code committee, or the ASTM committee. He's also, I guess, the chair of one of these committees. So we're providing a little bit of support, and also our staff is participating with that specification development.

In the area of design codes, there is very little information. There's no national codes for this. The U.K. and the Japanese have developed some aspects of design codes in these areas. We would hope to be able to get some information under the cooperation on their design process. But the initial parts of the research will be to review and evaluate what's already available from these two countries and see what improvements need to be made and then work with codes and standards committees to develop the design codes.

CHAIRMAN KRESS: Dana Powers had an issue with this graphite, it has something to do with energy build up through the irradiation. It's different than the Wigner energy, but it has higher level components to it that don't get annealed out to operating temperature. And he maintains that these could have significant energy releases during an accident condition when you get up to the higher temperatures and suddenly release these things. Does your research plan to look at any of that or the different --

MR. MUSCARA: It was not discussed in this current plan.

MR. FLACK: Yeah, we do recognize that and the plan. I think Don brought it up, Carlson.

MR. MUSCARA: As I said, it wasn't discussed in the materials.

MR. FLACK: If it wasn't in the materials part, I guess is the issue. I don't see Don here. Maybe you can bring it up.

CHAIRMAN KRESS: It's probably a severe accident issue or something.

MR. FLACK: Yeah, at the high temperatures the effects -- it seemed, the indication seemed, oh, Don just came in. Don Carlson will be up in a little while to talk about the nuclear analysis part of the plan.

The question had come up on graphite's behavior at higher temperature and not the Wigner energy, but the energies of releasing graphite at higher temperatures. The part, I believe there's a discussion of part of that in the plan.

MR. CARLSON: Yeah, I mention it in the nuclear analysis part, not that it's really a nuclear phenomenon but something you have to add to the decay heat power in analyzing these events.

CHAIRMAN KRESS: So it's in there?

MR. FLACK: It's in there. Yeah.

CHAIRMAN KRESS: Dana will ask that.

MR. FLACK: I'm sure he will. That's why we added it.

(Laughter.)

MR. MUSCARA: So I mentioned working with ASTM, eventually probably will work ASNE once we get some information about U.K. and Japan has been using. And as I mentioned earlier, we'll have a staff assignee to work in the U.K. to start addressing some of these issues and develop some consensus on what are the important parameters. For example, for the material specification, what are the important parameters for inducing irradiation damage.

As I mentioned, we do plan on establishing some international cooperation in the materials area, in particular, with Japan and with the European Communities. We have visited a number of countries to discuss materials issues among other issues. And we have shared our thoughts about research needed. Pretty much the thoughts are in the plan with both Japan and with the European Communities.

We've met the European Community representatives. They've reviewed our plan in one of their own independent meetings in Brussels. In effect, in the materials area, they decided that all this was important work and work that should be done. Some of the work is ongoing in their current program, but much of the work will be picked up in their next HTRM, M standing for materials program.

That's their sixth technology program. It will initiate in 2003. They're putting out requests for proposals at this time. They expect proposals at the end of this calendar year and they will initiate funding of their sixth program as I said in 2003.

So we have discussed participation with the EC and Japan and we're in the process of developing a draft agreement to do this. There is no exchange of funds, but it would be an exchange of research results from each other's programs. Some of the work going on in the European Communities, they're looking at a pressure vessel material for the high temperature gas cool reactor, but probably the next generation they're looking 9 percent chrome material. Of course, Exelon was planning on using the standard light water reactor material.

I believe at one time GA was intending on using the two and a quarter chrome 1 molley, but I think now they're also considering the 9 percent chrome. So the Europeans have begun work on the 9 chrome material. They will irradiate the material, both in welded and unwelded conditions. And they'll be conducting fatigue creep tests and irradiation tests.

They're also looking at two turbine blade materials. One material is aluminum, the other is chromium. So they have a chromoxide or an alumoxide coating that would form as a protective coating. And they're trying to determine which one might work best in a heating environment.

There's some work that they were planning on doing in the new program on in-service inspection methods, not necessarily evaluating the efficiency or the effectiveness of these inspections, but different methods that are needed for inspecting the reactors. And they also have begun some work on irritating graphite. As I've mentioned, they have five different graphites that they're going to be studying.

CHAIRMAN KRESS: Was there any work done in Canada with graphite?

MR. MUSCARA: Actually I don't know. I haven't looked.

CHAIRMAN KRESS: Mario seemed to think there was.

MEMBER BONACA: I thought they did some work in 1998.

MR. MUSCARA: We have looked at some of the literature. I'm sure not exhaustive, but nothing popped up from Canada. Most of the work I've seen has been European Communities and Japan. Of course, a lot of work is going on in Russia.

Well, some of the research that may not be picked up is international programs, at least not to the levels that I would like to see. It's work on the effect of the impurities on the degradation of materials. On the effectiveness of the service inspection is using a risk informed method for evaluating their effectiveness and on the correlations for the non-irradiated properties to the irradiated properties. And I believe that exchange of research results in these areas will buy us the results from all the other work that has been planned by the European Community and by Japan.

In addition in Japan, there has been considerable work done on the design and also on high temperature corrosion. And hopefully, we'll get access to that work also.

CHAIRMAN KRESS: There was some attempts to make correlations on non-irradiated material, properties for metals and had to do with dislocations and effects on the matrix. Is any of that applicable for graphite or completely different?

MR. MUSCARA: I am not sure. I have discussed with several experts. I think how many people talked what they said I would never get any correlations. Too difficult. Too many parameters.

CHAIRMAN KRESS: That's what I was wondering.

MR. MUSCARA: Others are fairly confident that now we could develop some correlations.

CHAIRMAN KRESS: It's certainly worth to look at it.

MR. MUSCARA: I've asked, I said we split about 50-50. I know it's been a lot of extensive work done in just the pressure vessel steel.

CHAIRMAN KRESS: Well, you know it doesn't look like trying to make such a correlation would be all that expensive because you're going to get the data anyway.

MR. MUSCARA: You certainly would get it, let's say, for one heat. But what we want to do now is for similar heat vary some of the important parameters. And then you have to be exposed to the irradiation. And you conduct side by side tests. And this is one thing that I suggested to the European Community that they're doing the other extensive work on five graphites, we ought to get together and decide on how best to make use on that work by doing some parametric studies on the side but coordinated with what they're doing. They liked the idea. They'd like to pursue that. But you can say the camp is divided at this point whether we're going to be successful in developing these correlations.

CHAIRMAN KRESS: That's always the case.

MR. MUSCARA: And I think if you look at the pressure vessel steel, you know, maybe they're right. This is much more complex material than steel.

MEMBER FORD: Joe, coming back to the whole question of privatization which we have based on something presuming to do with the risk. Half your input to that decision making process will come from other organizations. Don't necessarily have the same drivers as you will. So how useful is this specific data that's coming from the European Community or Japan? How useful will that be to solving your particular prioritized target? Do you understand what I'm getting at? You've got no control over what they're going to do. They may be completely irrelevant.

MR. MUSCARA: We have some especially for the new program. In fact, when I sent them our program, and they reviewed and I went back and discussed it, they said this is great. This is exactly what we need to do. Go do it.

MEMBER FORD: You said your program. What was in this document, the red one?

MR. MUSCARA: Yes.

MEMBER FORD: Okay.

MR. MUSCARA: But they were not as excited about some of the areas that I mentioned. So maybe they will take a little of the area but not as much. And the idea was there was that we would exchange information.

MEMBER FORD: When they say great, that's exactly what we need, is that because they weren't doing it?

MR. MUSCARA: They pretty much started out doing some literature reviews and assembling some data bases. They had done this for graphite, for pressure vessel material, and for turbine based material. Now that they've done that, now they're going beyond it. Now they need to get into doing research.

MEMBER FORD: So they haven't done any data collection themselves?

MR. MUSCARA: Very little so far. They've just initiated a pressure vessel program and their graphite, they purchased the graphites that they're going to expose. So, you know, they started about four years ago but a lot of it has been coming up to speed. What has been available? Where do they want to go? And what needs to be done? And so our plan came in about the right time, I think.

MEMBER FORD: That applies to both the United Kingdom as well as --

MR. MUSCARA: Well, this was more the European Communities. I'm not sure what role the United Kingdom is playing in this HDRM program. They have had, of course, on the graphite area lots of wrong data and experience. But as far as how does it apply, when we're working and reviewing the PDMR, and I looked at what Europeans were doing, my first thought was well, this is great, but it doesn't help me right now. Because they're looking at the next generation of steam generators. They're looking at higher temperatures. For example, the 9 chrome material.

So at one point I thought this is not

going to be that beneficial to us. But as the General Atomics design comes along and PDMR sort of is on the back burner for awhile, that work seems more and more appropriate. Because we were thinking ahead as to what might the materials be for the next generation of high temperature --

MEMBER FORD: And this international society of takeovers, etcetera, are any of the OEMs in Japan and European Community involved in this work and therefore by inference maybe General Atomics?

MR. MUSCARA: I don't think I understood.

MEMBER FORD: In collecting this data for the European Community HTR project and for the Japanese JAERI program, are any of the commercial manufacturers involved in this work?

MR. MUSCARA: Yes, some of the European work. In fact, the research will probably be conducted by people, for example, in the blade material. Some of the companies producing the material will be doing some of the research. So within the European program, it's not necessarily our national laboratories. A lot of commercial groups doing the work. In Japan, a lot of it is JAERI.

MEMBER FORD: Okay.

(Pause.)

MR. MUSCARA: I think, I guess, I'm at the summary. Did I pick up some time?

Well, we discussed a number of key technical issues and this relates to the chromes and standards of the availability and applicability of these standards. The lack of data in correlations for graphite. In my mind, environmental effects and degradation materials are a very important area that is not very well addressed. The pipe as a vessel, again, it's for the technical and the policy issue.

We need to determine whether that can be treated as a vessel based on the experience we've had and the lack of the experience for these materials to be used in a gas coal reactor.

CHAIRMAN KRESS: How does it compare in thickness to the vessel?

MR. MUSCARA: Typically the thickness of the duct pipe is about 1.6, 1.7 inches thick. So it's very much --

CHAIRMAN KRESS: Probably looks like a pipe.

MR. MUSCARA: It's a pipe. I asked this question in China about the pipe on the break and they essentially said to me no, we considered our vessels so we could avoid doing an analysis.

(Laughter.)

They could not do a smaller design for it.

CHAIRMAN KRESS: That's a wrong way to make a decision.

MR. MUSCARA: And I think that's a trick that has been played. It's not necessary because it really believes and behaves like a vessel. I think it's just get around this environment.

CHAIRMAN KRESS: If you had a risk basis for saying that this thing is not going to break at a certain frequency, then maybe you can do something like that.

MR. MUSCARA: And at that this stage I don't see how they can make the case without the data on the environmental effects, for example, and the appropriateness of creep and fatigue in their interaction.

CHAIRMAN KRESS: I don't either. That's the most likely place for a break.

MEMBER ROSEN: Your case wasn't made in a light water reactor with about 3,000 reactor years of experience in the United States. The case is now being attempted to be made based on experience that the largest pipe in the pressurized water reactor won't fail in a double ended guillotine manner. And there seems to be some staff acceptance of that, that it's going to be a very low probability event. But there's 3,000 reactor years of experience at the relevant conditions.

Now, to say the same thing is true for a plant without any experience just --

MR. MUSCARA: In different conditions, in different temperatures.

MEMBER ROSEN: At much higher temperatures.

MR. MUSCARA: It's a slight stretch.

MEMBER ROSEN: It's a big stretch.

CHAIRMAN KRESS: I think it's a stretch of misapplication on the design basis concept, too. Because in my mind the design basis concept says you select design basis accidents and you prescribe how you analyze them in a conservative way with certain tools and you have selected theories of merit for acceptance of the design. And you do that and lo and behold the whole reactor turns out to be safe over the whole spectrum of accidents.

Now the reason is because when you put in provisions and do the defense-in-depth parts that are required in the design basis case, those also deal to some extent with severe accidents.

MEMBER ROSEN: Most of them.

CHAIRMAN KRESS: Some of them. Most of them. So to take away one because oh, this isn't severe accident space because its frequency is so low it's not going to happen, is not the right concept design basis accident. You have to ask yourself if I take that away, have I now done something to the reactor that would put it a such a higher risk level that it's an unacceptable risk?. And I think that's kind of missing from that concept.

MR. MUSCARA: Even the data we experience we have today is especially for stress corrosion, cracking, and piping, and nozzles. We may not have had a break, but I think some cases might have come close. I mean, Duanne Arnold for example. Talk about this pipe. This thing have been of concern to me with respect to degradation.

I mentioned earlier that one of the designs there are jackets of insulation. They are going to the inside of this pipe.

Well, these jackets are about a foot to two long. And so they're several of these pieces that go in, which means I'm now naturally creating crevices. And has anybody looked at crevice corrosion cracking with the environment of the pure helium? And talking about that pipe being treated as a vessel. I mean, I can almost see a mechanism right now that could occur in these pipes when you have the insulation on the inside and creating crevices.

MEMBER ROSEN: Well, Joe, I don't think you need a lot more encouragement from the Committee to hold you position. I think you heard at least from myself and Tom and few others.

CHAIRMAN KRESS: Is that pipe still concentric? In the GTMHR concept it used to be a concentric pipe with a hot guise going one direction and the cold guise going back the other way. Is that still?

MR. FLACK: I believe it's the same design.

MR. MUSCARA: Let me sort of finish with the summary in just a few more words. So we haven't taken this lightly. We've looked at potential issues. We've written about them, discussed them. We in fact have initiated two small projects. One at Argonne National Laboratory to look at the basis for the design codes and standards for metals and to review in more detail than I have what information is out there on the effects of impurities, because I think that's a key area. And at ORNL we've started a project to start working with the standard specification, also to review what data and information on the potential for developing the correlations from the unirradiated to the irradiated properties. We planned on a having a 3-month assignment in the U.K. so we can learn more about graphite technology and experience and Dr. Srinivasan who was on our staff will be taking on the assignment.

MEMBER WALLIS: Do you have any problem with the language?

(Laughter.)

MR. MUSCARA: Really? Do we have any problem with the language. That's it.

CHAIRMAN KRESS: Thank you. I'd like to get a feel from the Committee whether they need a break or not.

MEMBER SIEBER: Sure do.

CHAIRMAN KRESS: This looks like a good time to take a 15-minute break. Why don't we come back at 25 after. 3:25.

(Whereupon, the foregoing matter went off the record at 3:12 p.m. and went back on the record at 3:27 p.m.)

CHAIRMAN KRESS: I think we'll get started again. We have most of us here.

MR. FLACK: Okay. Don Carlson and Richard Lee will now present their part of the plan, which deals with the reactor plant analysis.

CHAIRMAN KRESS: It's always a pleasure to have Richard here. We have him here so seldom.

MR. CARLSON: Okay. Again, my name is Don Carlson. I'll be presenting this with Richard Lee. It's about reactor systems analysis for advanced reactors.

The scope of reactor systems analysis encompasses three technical disciplines: nuclear analysis, thermal-hydraulics analysis and severe accident and source term. The research program will provide some data and validated system analysis tools that are appropriate for predicting system conditions and system responses in advanced reactors. A key point that you may have noted from Joe Muscara's talk is that, for example, the irradiation properties of graphite change such that thermal conductivity goes down considerably with irradiation if it is a function of irradiation temperature.

And a unique aspect of the new HTGR designs is that the maximum fuel temperature reached in say a conduction cooldown event is very strongly dependent on graphite thermal conductivity. So this hopefully puts some of those issues into a useful perspective.

CHAIRMAN KRESS: So your thermal-hydraulic analyses have to use the most irradiated, worst degraded properties of the graphite or --

MR. CARLSON: Exactly. For example, if you were doing a test in a prototype facility, if you did that early in life, you would get lower maximum fuel temperatures than if you did it toward the end of the graphite life.

CHAIRMAN KRESS: This is the concept of licensing by test?

MR. CARLSON: Yes, yes.

CHAIRMAN KRESS: It would have to have -- okay. There's some issues there.

MR. CARLSON: So these systems analysis tools that we'll be providing will allow the staff to independently check or confirm the applicant's analyses and get a better understanding of the technical issues, uncertainties and safety margins. The systems analysis will then also contribute to developing the regulatory framework by assisting in the identification of safety significant systems, components and licensing basis events.

The research plan addresses the three

major disciplines in separate subsections. I wrote all the sections in the plan dealing with nuclear analysis, both for reactor systems analysis and for the other three regulatory arenas: materials safety, waste safety, and as I mentioned earlier, we have a placeholder for safeguards as well. And all of those areas are heavy on nuclear analysis. But today we're talking only about nuclear analysis for reactor safety, and I'll be presenting that.

Richard Lee will be presenting the parts about thermal-hydraulics analysis and severe accident and source term analysis. That was the work of several different co-authors: Steve Bajourck, Tony Ullses, a little bit from me on HTGR thermal-hydraulics. Steve Bajourck was advanced light water reactors. Steve Arndt also wrote some of those input. And in the severe accidents area, Chester Gingrich and Ali Bebihani contributed those parts of the plan.

Now moving into the nuclear analysis area. Nuclear analysis is perhaps a term that has not been widely used in the NRC. I'm not the first to use it, but it encompasses everything concerning the interaction of radiation with matter. That is how I define the technical discipline. And so in the area of reactor safety, it would encompass core neutronics, both static and dynamic, which would include the evaluation of reactivity transients, temperature feedback coefficients for the fuel moderator and the reflector, reactivity control and safe shutdown and also would deal with spatial power distribution issues and issues such as local power peaking and oscillation stability.

Another type of calculation that's done in nuclear analysis is nuclide generation and depletion, sometimes referred to as nuclear transportation calculations. They're done for neutronics; that is, you analyze the core burnup to get the compositions used in your core neutronics calculations. Another main use for nuclide generation and depletion is calculating the decay heat power and also radiation sources and releasable inventories of fission products in the fuel.

A third area of nuclear analysis is radiation transport and attenuation. That would be find application for material activation and fluence damage in each TGR, as you're talking about fluence damage to graphite in addition to metallic components. And also you do, of course, radiation shielding calculations for radiation protection.

And then finally, although this isn't the subject of plan, there are nuclear analysis issues in out-of-reactor at the front end of the fuel cycle for criticality safety in the back end and fuel cycle criticality safety with burnup credit, decay heat and spent fuel, radiation shielding of spent fuel and non-destructive assay for safeguards.

CHAIRMAN KRESS: Your nuclide generation and depletion, is that origin we're talking about?

MR. CARLSON: That would typically be origin or cinder, yes.

CHAIRMAN KRESS: Oh, cinder, that's right, I forgot.

MR. CARLSON: We use origin. So starting off with advanced light water reactors, there are no significant new issues for AP1000, it's a lot like AP600 in current generation light water reactors, so the issues are the same. For IRIS, there are some new nuclear analysis issues concerning fuel depletion, modeling and validation for the fuel with five to eight percent initial enrichment that they'll be using in IRIS. The assembly lattices have a greatly increased ratio of moderator to fuel; that is, they're taking, essentially, a pin from 17 by 17 lattice and putting it in a 15 by 15 lattice, leaving more room for moderator.

They're using very strong, advanced burnable poison designs and burnup levels up to 80 gigawatt days per ton. The maximum burnups we see in current generation light water reactors are 60 gigawatt days per ton on an assembly basis.

Related to these depletion issues, there would be global core neutronics issues for the five- to eight-year straight-burn core. The IRIS does not do fuel shuffling. You load the fuel and burn it for five to eight years and then reload the whole core. The neutronics uncertainties and modeling issues would tend to compound more than you do with fuel shuffling, where in current generation reactors you have a relatively fresh assembly in close proximity to the higher burnup assembly, so that tends to wash out the effects of depletion uncertainties.

And, finally, you have decay heat power modeling and validation issues. Probably you need for an extension of the ANS 5.1 decay heat guidance that would be applicable to this new fuel and the higher burnups in particular.

Now, for some of the research activities that we would be doing for IRIS, first of all, we would identify relevant reactor physics to benchmark data. There have been light water reactor benchmark data for higher burnup fuels developed in various places in recent years. There was the REBUS Program that the NRC was involved in in Belgium. In Switzerland, there is the ongoing LWR PROTIS Program. And there were the series programs in U.K., France and the U.S. involving experiments at Catarash on the Ecole and Minerva facilities. And then there is also an ongoing nary-funded program at Sandia for doing measurements related to burnup credit that would have some applicability to IRIS.

CHAIRMAN KRESS: Now, what is this data about? Is it about the buildup of nuclides or is it about decay heat or --

MR. CARLSON: This would be critical benchmark data --

CHAIRMAN KRESS: Critical data.

MR. CARLSON: Critical benchmark data for the fresh material and for fairly high burnup material.

CHAIRMAN KRESS: Okay.

MR. CARLSON: And there would be some radioisotope assay data afterwards, destructive assay.

CHAIRMAN KRESS: But this involves all your cross-sections and --

MR. CARLSON: So there would be origin-type depletion validation.

CHAIRMAN KRESS: This involves all your cross-sections then and the --

MR. CARLSON: Yes. It involves the cross-sections and all the tools that use the cross-sections.

CHAIRMAN KRESS: And those are things like PDQ? What code do you use in these things for that?

MR. CARLSON: Well, the NRC is in the process of developing for the first time a lattice physics tool.

CHAIRMAN KRESS: PARCS, was that the name of it?

MR. CARLSON: PARCS is our diffusion theory code. It's a global 3D kinetics diffusion theory code. And we're developing a lattice physics tool that would produce data for use by the diffusion theory code.

CHAIRMAN KRESS: This is a code to benchmark against this data.

MR. CARLSON: And so those suites of codes would be benchmarked against these data.

CHAIRMAN KRESS: Putting in the right cross-sections and stuff for the -- well, this is IRIS, I guess it doesn't need any -- doesn't need much changing.

MR. CARLSON: Yes. Like I said, the changes are there's a greater use of burnable poisons, there's an increased moderator fuel ratio, and so we would have to look for data that gets you more into those physics regimes.

CHAIRMAN KRESS: What does that effect, the energy distribution of neutrons?

MR. CARLSON: Yes. You get a softer thermal spectrum.

CHAIRMAN KRESS: Softer thermal spectrum.

MR. CARLSON: And, of course, we're pursuing international cooperation through the AIEA, the European Commission and OECD/NEA. And these would be conduits for getting to some of these data that I mentioned.

The general approach that we would like to pursue in the international cooperation would be to use high order methods like continuous energy Monte Carlo as a code-to-code benchmark against the more proximate practical methods that you use for reactor physics.

The HTGRs, the GT-MHR and PBMR, share some similar features with regard to nuclear analysis. They both, of course, use fission products retaining coated fuel particles, graphite as the moderator and neutronically inert helium as the coolant. Moderation by graphite gives you a prompt neutron lifetime, about 20 times what you get in light water reactors. The migration links in graphite is 62 centimeters versus 5.8 centimeters in water. It takes about 114 collisions to thermalize a neutron with graphite versus 18 collisions on the average with water. So they're a very significant physics from what we're used to in light water reactors. The large migration area bottom line there is that an HTGR is much more tightly coupled neutronically than a light water reactor of similar dimensions.

CHAIRMAN KRESS: It sounds to me like those were good things you were saying about the --

MR. CARLSON: Oh, yes. They're good things.

MEMBER SIEBER: Except for the prompt neutron.

MR. CARLSON: Well, the prompt neutron lifetime is good too. It's a longer -- you get much wider prompt pulses if you get any.

MEMBER SIEBER: Okay.

CHAIRMAN KRESS: What's the issue with the long annular cord geometry? Does that --

MEMBER ROSEN: Axial stability?

CHAIRMAN KRESS: Does that cut down on your --

MR. CARLSON: At some point, you get into axial stability issues, the mode separation of the fundamental from the higher harmonics goes away eventually if you get long enough.

MEMBER WALLIS: Does the helium produce significant moderation or is that negligible?

MR. CARLSON: That's negligible.

MEMBER WALLIS: Negligible.

MR. CARLSON: Both reactors use control and shutdown absorbers located in the graphite reflector regions.

CHAIRMAN KRESS: I understand that you have significant moisture ingress, that you might have some neutron effects with the coolant if you had a leak, had a moisture leak or something, you might have a problem with?

MR. CARLSON: Well, in the old designs that use steam cycle, that was a more likely event, where you had high pressure water systems interfacing with the primary system. In these Braten cycle systems, you only have low pressure water, but still you would have to consider moisture ingress for depressurized or underpressurized conditions in the primary. And what happens in a moisture ingress is you're adding hydrogenous moderator to an undermoderated system, so K-effective goes up.

CHAIRMAN KRESS: You're adding positive reactivity.

MR. CARLSON: You're reducing the prompt lifetime, you're decreasing the migration links so fewer neutrons are getting to the absorbers and the reflectors, so you're reducing the reflector absorber work.

CHAIRMAN KRESS: Don't you have to have a lot of water to do that? I mean it's going to be steam when it gets in there.

MR. CARLSON: A little water goes a long way for slowing down the neutrons. It really takes over the slowing down term just a little bit.

CHAIRMAN KRESS: I would have thought you had so much graphite in there, you wouldn't even know if this water was there.

MEMBER ROSEN: Can you quantify that? That's an interesting result. I mean just how much is a little?

MR. CARLSON: I can't quantify that. I could, but I'm not --

MEMBER ROSEN: Well, a little helium goes a long way too but not quite as far, I guess.

MR. CARLSON: Well, helium is neutronically inert. Graphite is a very powerful scatterer, a very powerful slower down.

MEMBER WALLIS: Well, helium is a slower down too. Helium is a slower down.

MR. CARLSON: Yes, but there's just not enough helium atoms to have a significant moderation effect. It's a gas.

MEMBER WALLIS: But it's under pressure.

MR. CARLSON: Yes. So unlike --

MEMBER WALLIS: Water is going to be liquid in this thing?

MR. CARLSON: No, there will be steam. It will be --

MEMBER WALLIS: It would have to be gas too.

MR. CARLSON: The steam, yes. Helium also has a very small cross-section of hydrogen.

Unlike the earlier HTGRs, the Fort Saint Vraian and the THTR, these newer designs use thorian instead of -- the older designs use thorian and HEU; the newer designs use low-enriched uranium. In the case of the PBMR, eight percent in the equilibrium core. They start out with four percent in the initial core. And in the case of GT-MHR, 19.9 percent initial enrichment. As we said before, they have long annular core geometries with control and shutdown absorbers in the reflectors. These similarities then do lead to fairly similar modeling and validation issues for the two design concepts.

Some of the issues that are discussed in the plan, the temperature coefficients of the reactivity. It is claimed that both designs have a very strong negative temperature feedback. The components are temperature coefficient of the fuel, the moderator and the reflector. The first two are strongly negatives, and the last one is positive.

CHAIRMAN KRESS: And in fact that's the reason the temperature never gets above the 1600 because of the temperature coefficient?

MR. CARLSON: It sets itself down.

CHAIRMAN KRESS: So it's important to know that.

MR. CARLSON: In fact, one way -- the favored way of shutting these down is to simply turn off the coolant.

CHAIRMAN KRESS: It shuts it down and then you get the xenon buildup to keep it down. But the xenon decay --

MEMBER ROSEN: And all of a sudden you return to power.

CHAIRMAN KRESS: Yes, the xenon decay would come back to power then?

MR. CARLSON: Yes. After about a day, xenon decay and then you didn't put in absorbers, then you would eventually --

CHAIRMAN KRESS: Then it would just sit there an oscillate.

MR. CARLSON: Then you oscillate at low power.

CHAIRMAN KRESS: Low power.

MEMBER ROSEN: So would you say that again? The fuel and the moderator are strongly negative.

MR. CARLSON: But the reflector temperature coefficient is positive. So if we could figure out a sequence where you heat the reflector without heating the fuel in the moderator, you would have positive feedback.

CHAIRMAN KRESS: Overall, you have positive coefficient.

MEMBER ROSEN: Overall?

MR. CARLSON: Overall, you have a strongly negative.

CHAIRMAN KRESS: Strongly negative. You have a strong negative overall.

MEMBER ROSEN: Right. Because if it was overall positive, you might as well stop.

CHAIRMAN KRESS: Yes, yes.

(Laughter.)

MR. CARLSON: Well, one question that I was kicking around is when you return to criticality, if you don't scram after xenon decay, you have a combination of xenon decay and perhaps some cooling from the conduction, and you're cooling from the outside in. The peak temperatures are in the middle.

CHAIRMAN KRESS: Oh.

MR. CARLSON: And so the reactivity at the periphery is higher, so that may give you -- accentuate your positive feedback.

CHAIRMAN KRESS: Yes. That could be real excursion, couldn't it?

MR. CARLSON: So, well, that would be interesting to see what kind of excursion it gives you.

CHAIRMAN KRESS: That won't take place for two or three days, right?

MR. CARLSON: That's right. That's right.

And, obviously, that's one where you would need spacial kinetics to do it properly.

The issues of worth of reactivity control and shutdown absorbers, there have been experiments done in recent years to help validate those calculations, and it remains to be seen what kind of tests will be done in the first modules of the designs.

We already discussed moisture ingress reactivity. Reactivity transients, I'll discuss that a little bit more later, but that's an important issue in terms of what kind of testing needs to be done on the fuel.

There's little or no in-core instrumentation. In a pebble bed, there are no structures to accommodate in-core instrumentation, and even in a prismatic design the temperatures are too high to allow much instrumentation. So that gives you issues of what can you do with ex-core instrumentation, and that's clearly a nuclear analysis issue that will require careful consideration. Clearly, the lack of in-core instrumentation may leave you with some uncertainties in terms of how far you can go in validating your nuclear analysis methods.

MEMBER SIEBER: I would imagine doing a

calimetric on a pebble bed would have more uncertainty than you would out of a ranking cycle.

MR. CARLSON: So there would be uncertainties overall in the thermal power is what you're saying.

MEMBER SIEBER: Right.

MR. CARLSON: I haven't really considered that. That's a good point.

MEMBER SIEBER: Well, but that's how you calibrate your ex-core instruments. So you're sort of out in there a little bit of no-man's land, a little bit.

CHAIRMAN KRESS: MC sub p, delta P.

MEMBER SIEBER: Pardon?

CHAIRMAN KRESS: MC sub p, delta P.

MEMBER SIEBER: Yes, but because you don't have heat of vaporization in there, you have to really know what the flow is --

CHAIRMAN KRESS: The flow is pretty close --

MEMBER SIEBER: -- and the temperatures.

CHAIRMAN KRESS: -- to delta p.

MEMBER ROSEN: Why is that a challenge, Jack? I mean you can measure the flow, can't you? You can measure the delta p pretty accurately.

MEMBER SIEBER: But the spread is not real big. The difference between a primary calimetric and a secondary calimetric. It's the heat of vaporization that really gives you the accuracy there. And it's 1200 Btus.

MEMBER ROSEN: What is the core delta p typically on these machines?

CHAIRMAN KRESS: Nine hundred minus 600, I think.

MR. CARLSON: About 300, 350.

MEMBER SIEBER: It's 200 to 300 degrees.

CHAIRMAN KRESS: Something like that.

MEMBER ROSEN: Sounds like enough to measure.

MEMBER SIEBER: Well, I think you can measure it. The flow is the tougher one, because it's a pretty light density material.

MR. CARLSON: And during Joe's talk, we mentioned the graphite and helium heat sources, although the graphite is operated at temperatures so that you don't get a significant accumulation of wigner energy; that is, continually. There are some higher energy graphite distortions that accumulate, and those only anneal during accident heat-up events. And that's an exothermic annealing so that becomes a heat source that you add to your decay heat source term. And, actually, the convention wisdom is that the dominant effect is that you recover some thermal conductivity in the graphite.

CHAIRMAN KRESS: You should note that you're giving this talk and Dana is here.

(Laughter.)

MEMBER ROSEN: So it's a good thing, right?

MR. CARLSON: I'm not saying I have concluded that, but others have concluded that the dominant effect is the recovery of thermal conductivity.

Some unique issues to the GT-MHR, in addition to fissile particles that are 19.9 percent U2-35, you have fertile particles that are natural uranium, so that's a unique challenge for modeling and validation right there. Also, burnable poisons and the zoning of fuel and poison loading is to give you the power shaping to limit peak powers.

For the PBMR, you have a very different core. You have a random loading of pebbles and continuous online loading where you measure the burnup of each pebble as it comes out and either put it back in the reactor of discharge it, depending on what the measured burnup is. The target maximum burnup for the PBMR is 80 gigawatt days per ton, so at what measured burnup do you discharge? And that becomes a question of how much additional burnup can you get on that last pass through the core, and that's a question of what's the residence time spectrum of pebbles on the final pass through the core?

I think one issue that the PBMR --

CHAIRMAN KRESS: How will you ever get that information, because it will depend on the level of burnup or the level of irradiation that the pebbles experience. And the way you're going to test that is with fresh pebbles somewhere outside to see what --

MR. CARLSON: What the residence time spectrum is?

CHAIRMAN KRESS: -- the residence time is.

MR. CARLSON: Well, actually, in AVR, they've got a pretty good measurement of residence time spectrum, and they did somewhat in THTR just by --

MEMBER SIEBER: That's the distribution, though, right?

MR. CARLSON: That's the distribution.

CHAIRMAN KRESS: You'll have to treat as a distribution.

MR. CARLSON: It will be a statistical argument, yes.

And there's an issue of using the four percent enriched fuel in the initial core, and do you really want to drive that to 80 gigawatt days per ton, and I don't think that's an issue that the PBMR design team has grappled with. My guess would be that you would want to discharge those at a lower burnup, but you can't distinguish between what the initial enrichment of a pebble is by measuring its burnup.

CHAIRMAN KRESS: That's right.

MR. CARLSON: So I see a bit of quandary here.

Some of you may have heard about the hot spots issue. I worked in Germany, and the AVR reactor was outside my window when I worked there for five years. One of the experiments they did there was a melt-wire experiment where they loaded 200 graphite pebbles, graphite only, no fuel in them, with melt wires, 20 different melt wires. The maximum melting temperature of the melt wires was 1280 C. And what they didn't expect was to get all those wires melting in any of the pebbles, but what they did in fact see was that ten to 20 percent of the pebbles had all the wires molten, indicating that the maximum coolant temperature, not the fuel temperature, the maximum coolant temperature seen by the pebbles was over 1280 C. So that's the hot spots issue, and it's not resolved. Perhaps the bottom line is that any new pebble bed reactor that's built will have to do melt wire experiments or something equivalent to that, both for the initial loading and perhaps the transitional and equilibrium cores as well.

MEMBER SIEBER: It's not clear how you would solve the problem, though, once you recognize that it was there.

CHAIRMAN KRESS: But you have to deal with it like we do the hot fuel channel in the LWR, treat it like the --

MEMBER SIEBER: Operate below the --

CHAIRMAN KRESS: Yes. You have to have some criteria for the hot spot.

MR. CARLSON: Just as a side note, when Exelon and the PBMR design team presented to us in June of last year, they were saying the maximum fuel operating temperature in the PBMR would be, what was it, 1100 --

CHAIRMAN KRESS: Twelve hundred.

MR. CARLSON: -- less than 1200. I think it was going to be 1060 --

CHAIRMAN KRESS: Yes.

MR. CARLSON: -- for maximum outlet temperature of 900 C. And I just said, "Did you consider the results of the AVR melt wire experiments?" And their answer was, "Not really." And I guess at our last meeting with them where we discussed this, they were saying the maximum fuel operating temperature is now 1300 C, something like that. And still nobody knows, and they won't know until they do a melt wire experiment or something like that in the first module.

MEMBER SIEBER: Even those aren't really the maximum temperature, right? It's a non-fuel ball.

MR. CARLSON: Yes.

MEMBER SIEBER: And so some fuel ball is going to have the maximum temperature.

MR. CARLSON: The best that can do is tell you the maximum local coolant temperature in the core.

MEMBER SIEBER: Right.

MEMBER ROSEN: It doesn't tell you that either. It tells you the maximum measured molten fuel.

MR. CARLSON: Yes.

MEMBER ROSEN: There may be a pebble that wasn't measured that was hotter.

MR. CARLSON: Maybe 200 melt wire pebbles isn't enough to give you a good sampling.

And then there are a number of issues of analytical treatments of the quasi-random local mixing of pebbles with different burnups, different fission powers and different decay heat powers.

MEMBER SIEBER: Do we know the degree of randomness of the distribution of these spheres?

MR. CARLSON: I would say no. I don't think there's been ever a direct way of measuring what is the clustering of first pass pebbles.

MEMBER SIEBER: Straight through the middle or --

MR. CARLSON: Well, there have been experiments done, and there have been measurements done on operating reactors that give you the residence time spectrum, and it gives a velocity profile that the pebbles move faster through the center of the core than they do at the core periphery and those kinds of things.

MEMBER SIEBER: Well, I would imagine you would build up a lot of fairly high burnup fuel on the outside and all the stuff you're putting in with it down through the middle.

CHAIRMAN KRESS: But how do you load this?

You load the fuel in the annular region off the top.

MR. CARLSON: Yes.

CHAIRMAN KRESS: Is it put in kind of distributed across the whole thing?

MR. CARLSON: There are nine different loading tubes around the periphery.

CHAIRMAN KRESS: And you drop them right in the middle of the annulus?

MR. CARLSON: In the middle of the annulus. Well, I think they still have a porous central reflector, although that may go away. But if they have a pebble central reflector, then they have a single central loading tube for that, for those graphite-only pebbles.

CHAIRMAN KRESS: Those are graphite-only.

MEMBER ROSEN: And you've purchased a set of body armor for your discussion with the ACRS, the full ACRS later this week when Dana Powers is here, on this subject?

CHAIRMAN KRESS: I would recommend you sit over where Richard is.

MR. CARLSON: For the pebble bed mechanics issue, the net mixing and flow of pebbles?

CHAIRMAN KRESS: Yes, I would recommend you sit over where Richard is, because Dana will be sitting on that corner.

MEMBER ROSEN: He's been coiling up for about two years on this subject.

MR. CARLSON: Well, that was one of the interesting things we discussed when we visited Germany last summer was the lessons learned from the THTR. They had predicted a given pebble flow velocity profile, and what they got was quite different, because the tests that they had done were scaled room temperature tests in air.

CHAIRMAN KRESS: Yes. I think what you'll hear from Dana, though, is he'll say, "Right on. You've got the right issues, you're thinking right." So I don't think Dana will be given him any problems. He'll just be saying, "Yes, yes, you've got the right idea."

MEMBER SIEBER: Well, it's a question, and I guess that that's the idea you ought to have, right?

CHAIRMAN KRESS: Yes.

MEMBER SIEBER: Instead of making an assumption.

MR. CARLSON: And in addition to the nuclear analysis issues directly for reactor systems analysis, there are some nuclear analysis studies that are needed to support the TRISO Fuel Testing Program.

The first one, as we alluded to briefly before, was reactivity transients. For defining the accident testing requirements, we need to define the worst case power transients that could arise from a credible reactivity accident, like a prompt pulse in a given HTGR design. We conclude that promp pulses are credible, we should try to consider the appropriate pulse width in addition to the energy distribution. There has been some pulse testing of fuel done in Japan and Russia, but to my knowledge, they used pulse widths on the order of ten to 30 milliseconds. Whereas in a graphite-moderated reactor, the real pulse widths are more on the order of 500 milliseconds.

CHAIRMAN KRESS: How do you get a prompt pulse in a graphite reactor? Do you have reject a rod?

MR. CARLSON: You'd have to reject a fairly high-worth rod or a bank of rods.

CHAIRMAN KRESS: That's about the only way I can think.

MR. CARLSON: Now, people have discussed pebble bed -- seismic compaction of a pebble bed --

CHAIRMAN KRESS: Oh, yes.

MR. CARLSON: -- as a way. The German

analysis concluded that you could only get about a little over one percent compaction. The theoretical compaction you could get would be over ten percent,in which case that would be well over prompt critical.

And also we have out-of-pile accident testing. The heat-up testing that Stu referred to and the pulse testing that has been done to a limited extent in Japan and Russia were done after irradiation with some time interval between irradiation and testing of days or months even.

CHAIRMAN KRESS: Yes. That's always the case.

MR. CARLSON: And that's the same for light water reactor fuel, and there has been an issue with that. So a similar issue applies. We need to do some nuclear analysis to evaluate how the radionuclide decay and other physical changes that occur before out-of-pile accident testing affect the radionuclide inventories that affect fuel performance in those accident tests. And, of course, the physical changes would be things like chemical reactions and phase changes.

Then, finally, for the irradiation in test reactors versus HTGRs, since most of the fuel irradiation testing has been done in test reactors rather than HTGRs, we need to consider how the radionuclide inventory, as it affects fuel performance, are affected by the non-prototypicality of those irradiation in terms of the accelerated burnup rates and the non-prototypic fuel temperature histories, the neutron fluences and the neutron energy spectra.

The rate of plutonium production and the ratio of plutonium fission to uranium fission is known to be pretty sensitive to neutron energy spectrum. So those are the kinds of things we would look at. The yield of significant fission products that is significant to fuel performance from plutonium fission versus uranium fission is significantly different.

CHAIRMAN KRESS: Yes. Now, when you say this is something you have to look at, you know, you've got the codes, you've got the cross-sections, and what I envision these tests in, say, the test reactors were just a way to validate the code predictions, how well did the code predict that. And then you say, okay, my code has the right cross-sections and stuff, so I can predict an actual HTGR because I know the cross-sections of plutonium, and I know the energy spectrum I'm going to get is going to be different, but I can account for it. What do you mean when you say you're going to look at? You're going to do more --

MR. CARLSON: We do some calculations. Let's take an irradiation in HFR or the ATR or the HFR.

CHAIRMAN KRESS: You do it in a variety of reactors that you can.

MR. CARLSON: And calculate the spectrum that the fuel sees in those tests. Calculate the spectrum that you see on actual HTGR --

CHAIRMAN KRESS: Power those.

MR. CARLSON: -- irradiation. Take account to the accelerated burnup if you have that. And compare the nuclide inventories you calculate with one versus the other. If there are significant differences, then we should factor that into interpreting the applicability of the test results.

CHAIRMAN KRESS: Or the applicability of the code calculations. I view this just like thermal-hydraulic. You know, you validate them in non-prototypic conditions, but you figure the range of --

MR. CARLSON: Well, I don't think any of these tests validate the nuclear codes.

CHAIRMAN KRESS: You don't view them in that light?

MR. CARLSON: No. Their purpose is to test the fuel, and I think they have little or no value for validating the nuclear methods.

CHAIRMAN KRESS: Okay. Could they be used for that?

MR. CARLSON: You would have to retool -- they'd have to design the experiment to really get what you want for nuclear analysis validation. And there are facilities that are designed to really do that sort of thing.

Some of the research activities that we're starting or planning on soon starting for the GT-MHR and PBMR, the advanced HTGRs, number one, we're -- first, we've started to prepare modern nuclear data libraries based on the latest data evaluation files in ENDF/B-VI.

CHAIRMAN KRESS: Who is the custodian of that data?

MR. CARLSON: Brookhaven.

CHAIRMAN KRESS: Brookhaven.

MR. CARLSON: Brookhaven is ENDF/B-VI custodian.

CHAIRMAN KRESS: Okay.

MR. CARLSON: Back in '96, when I was in NMSS, I initiated a user need for research to update the Apex code system, which is a code system at Oak Ridge that is used to process the evaluated nuclear data from ENDF/B-VI or the foreign counterparts, JEFF-3 or JENDL-3.2, into actual cross-section libraries. And that's exactly what we've started now that -- in response to that user need, now that the Apex code has been upgraded to do that job, and there's also the NJOY code at Los Alamos that can do part of that job. We're going to use those tools to generate state-of-art cross-section libraries to ultimately replace the libraries that are in use today in the NRC, which are mostly from the 1980s and based on ENDF/B-IV and ENDF/B-V.

So we're talking about multi-group libraries with perhaps 400 to 500 energy groups that would generically applicable to all reactor types, not just HTGRs, including current generation light water reactors and would be used for all in-reactor and out-of-reactor nuclear analysis applications.

MEMBER SIEBER: Just for my own education, what do we know now about ENDF/B-VI data that we didn't know in version III or IV?

MR. CARLSON: There's a whole list --

MEMBER SIEBER: Is it new measurements?

MR. CARLSON: There are some new

measurements. There are improvements in the tools used by evaluators when they take those measurements to connect the points, so to speak. Significant improvements there. There have been plain glitches that have been caught. I had a hand, some 11 years ago, in catching a problem in the S-alpha/beta bound thermal scattering data in ENDF/B-VI and actually had gone back to ENDF/B-I. And it was particularly significant for graphite.

MR. LEE: And also in the Apex code, the suite of codes that we developed, the residence treatments are better now, either in the resolved or unresolved residences. So those tools have been developed now, so we need to process the data to get these cross-sections for application.

MR. CARLSON: The ENDF/B-VI formats greatly increase the resolved energy range, the resolved residence range for the data.

MEMBER SIEBER: Do you see improvement in the use of that in 3-E diffusion calculations as far as accuracy of predictions or --

MR. LEE: I think in our recent staff application in the, for example, the peach bottom turbine trips --

MEMBER SIEBER: Okay.

MR. LEE: -- one, the reactivity assertions you can see some difference between applying the two different type cross-sections.

MEMBER SIEBER: So it's a worthwhile endeavor to do this.

MR. LEE: Yes, definitely.

MEMBER SIEBER: Okay. Thank you.

MR. LEE: Across the board.

MR. CARLSON: And it shows up in the depletion analysis and in shielding calculations everywhere.

Also, we're starting scoping studies for core neutronics and decay heat analysis. The general approach is to use high-order methods, like continuous energy Monte Carlo, NCNP, and do very exact models with exact geometries and gradually introduce the approximations and more approximate methods that are used in practical reactor analysis codes to understand what the effects of these approximations are and what would be acceptable modeling practices and their range of applicability.

We've initiated some PARCS code modifications to incorporate an R-theta-Z geometry that would be needed for analyzing a pebble bed reactor.

MEMBER SIEBER: Okay.

MR. CARLSON: And we envision some PIRT exercises that would be focused on the reactor systems analysis area, including nuclear analysis to identify and more systematically prioritize the particular needs to data and modeling capabilities.

We're also planning some cooperation with MIT on a core depletion analysis tool that would build upon the peb bed code that's been developed in conjunction with INEL. And we're pursuing opportunities for HTGR-related domestic and international cooperation to get access to physics benchmark from various sources. We'd be going first through the IAEA. There's a cooperative research program, Number 5, that's been ongoing since 1998 and scheduled to go through 2004. That has been looking at the initial criticality and physics data from the HTGR in Japan and the VHTRC critical -- the heated critical experiment facility there; also, the HTR-10 initial criticality and subsequent benchmarks from China; the Astra Facility at the Kurchatov Institute in Russia that has been -- those are pebble bed experiments with in-reflector absorbers that have been sponsored by PBMR.

And then the HTR PROTIS experiments from

PSI in Switzerland that were done in the early '90s. That was an international program. And, finally, some data from France, Germany and the U.S. and U.K. I was involved when I was at Los Alamos in the CNPS critical experiments, and those would play a role.

In addition, as part of the international cooperation, we're considering providing U.S. NRC assistance, both in the technical aspects of the testing programs but also in the QA areas to make sure that the quality assurance is adequate, that we can actually make full use of the results from the testing programs.

So now that concludes the nuclear analysis. I can turn it over to Richard.

MR. LEE: Starting with the AP1000, as you know, this application is in-house, and NRR is planning to issue a draft SER sometime in June of next year, following with a final SER by the end of fiscal year FY '04. Related to the AP1000 back in February 14, the research and NRR staff has briefed the Subcommittee in detail about the AP600 scaling and how it is applied to AP1000. And I think you know a lot more about AP1000 thermal-hydraulic analysis requirements for this application in details.

As you know that the -- we said that most of the work that we have done in support of AP600 means the Apex facility at Oregon State University, all those tests are applicable, accept that we believe that the range and some of the conditions need to be extended for applicability to AP1000 and mostly related to the steam production, high-costing production that resulted in high entrainment for horizontal stratified flow and the upper plenum pool entrainment. Both experiments are ongoing at this time.

MEMBER SIEBER: Who's doing those, Westinghouse?

MR. LEE: Westinghouse is doing the integral effects. They modified a facility --

MR. ELTAWILA: Correction.

MR. LEE: No, not that one.

MR. ELTAWILA: This is DOE testing, not Westinghouse.

MR. LEE: Oh, DOE.

MR. ELTAWILA: DOE.

MR. LEE: Yes. I should say DOE.

MEMBER SIEBER: But the entrainment issue --

MEMBER ROSEN: That's done at Oregon State.

MR. LEE: Yes. It's been done at Oregon State at the integral facilities.

MEMBER ROSEN: With DOE funding.

MR. LEE: DOE funding, right. What NRC is doing with that, before they change configuration, there are some certain other conditions that we'd like to test. Those tests are sandwiched between the DOE testing. And I believe we are also doing some separate effect testing, looking at the entrainment phenomena details.

MEMBER ROSEN: All of this will support the 2004 SER?

MR. LEE: Yes. I think even before that. I think by beginning of next year I believe that we need to get our codes in shape.

MEMBER WALLIS: This entrainment from horizontal flow, what is that?

MR. LEE: I think it has to do with the Ts.

MEMBER WALLIS: That's the ADS for T.

MR. LEE: Yes, that's correct.

MEMBER WALLIS: So it's entrainment at a T, really.

MR. LEE: As a T; yes, that's correct.

MEMBER SIEBER: Well, it sweeps across the top of the core and carries water that's supposed to be cool in the core out of the break.

MR. LEE: That's right.

MEMBER WALLIS: Carries it out the ADS fall line.

MR. LEE: It's the ADS fall line that we're talking about, right, and the concern about --

MEMBER SIEBER: And that's different because the ADS system is different between the 600 and 1000.

MR. LEE: That's correct. Right. Especially ADS. Those are ongoing. Then another thing to talk about is the low pressure critical flow. We are doing some testing at the Purdue University, and that is basically to look at much lower found in 150 psi regions for critical flow. They are mostly at the high pressure. This ECCS bypass direct vessel injection, those are being looked at, the data from Korean's program.

For the IRIS reactor, as you know, that the steam generator pressurizer cooling pumps, everything is located inside.

CHAIRMAN KRESS: What is meant by modular in this sense? Is it the components are modular or you have modules of reactors?

MR. LEE: I think it's a small unit, so I guess they can build --

CHAIRMAN KRESS: Use three or four of them to get 1,000 megawatts? Because some people speak of modular as the parts are modular that go into --

MR. FLACK: It could be also modular, but in this case they're talking about the reactor themselves as being modular of anything more than one site.

CHAIRMAN KRESS: More than one.

MR. FLACK: You have several of them to a site.

MR. LEE: Right. You can see that the power is about this much. And the size of the whole vessel is about 60 feet tall, so it's about almost two times the height of a current reactor, the pressure vessel.

The issues that we look into of course has to do with -- the steam tubes that they use are different than current design, because this promotes very good T transfer because of the heat transfer. Then the reactor also relies on a lot of natural circulation. About 40 percent of the core flow are driven by natural circulation during an operation. And then another thing is that the way that the -- if anything happens, the RCS gets depressurized to a very low pressure and close coupling between the containment and the RCS, just like passive reactors we have now. For the SBWR or the AP1000, there's a close coupling between the containment RCS.

CHAIRMAN KRESS: You're going to have to hook -- does MELCOR core already have that coupling in it?

MR. LEE: We're not doing anything right now on it, but, yes, we do have the containment and the --

CHAIRMAN KRESS: I guess the new track M would have to be connected to something like contained to evaluate the thermal-hydraulics for the strong coupling between the containment and the primary system?

MR. LEE: Yes.

MR. ELTAWILA: Yes. Right now, the TRAC-M code has a very simple containment model, so you can use it. But the long-term plan is to couple the contain code to the TRAC-M code.

CHAIRMAN KRESS: That's all you're really looking at is the back pressure effects on the blowdown, which you could use a simple model for that thing.

MEMBER WALLIS: Blowdown is from a steam line break; is that what it is?

CHAIRMAN KRESS: Yes. You've got the steam -- that's the only place --

MR. LEE: That's the only one coming out from this reactor. That's the only thing that is coming in is the stream generator feed and the one going out.

CHAIRMAN KRESS: A small volume, strong containment, so that it builds up in pressure pretty fast.

MR. LEE: Right. It's a very small containment.

CHAIRMAN KRESS: So it affects the blowdown rate. That's probably the only thing it affects, I'm not sure.

MR. LEE: Right. And then as you --

MEMBER WALLIS: The primary water can't get out?

CHAIRMAN KRESS: Well, that depends on whether you have a steam generator tube rupture, I think.

MEMBER SIEBER: It gets out.

CHAIRMAN KRESS: I think that's the only way.

MR. ELTAWILA: According to Westinghouse, you can run with a LOCA forever.

CHAIRMAN KRESS: That's with water. But I think you have to rupture the steam generator tubes to get water out, unless you can get a break in the vessel itself, which is --

MEMBER SIEBER: That's right.

MEMBER WALLIS: You presumably have smaller breaks. You presumably have make-up water for the vessel or something. You must have some lines.

CHAIRMAN KRESS: Well, you may have control rods going in. I don't know what the penetrations are, but you may have some control rods.

MR. LEE: The control rod guide tubes are coming in from the top, but my understanding is that those can be even relocated into the vessel. That's what we mentioned.

MEMBER WALLIS: So those can break. Those can break, even after you solve the problems we have with the control rod.

MR. LEE: That's one.

CHAIRMAN KRESS: You may have to rupture the head to get a leak.

MR. FLACK: Actually, we have somebody from Westinghouse here that can speak. You can use the microphone.

MR. ORIANI: I'm Luka Oriani from Westinghouse Science and Technology Department, and I'm working on the IRIS design. We actually are considering some intermediate and medium-size LOCA because we will have some piping. For now, the assumption is that the largest piping will be a four-inch pipe, more or less.

There are also some differences in the design with respect to the considerations that have been presented here. Like, for example, the degree of natural circulation is much lower. That 40 percent was referred to is more a size of the IRIS reactor that was initially foreseen, and the parallel channel flow instabilities should be less of a concern, because the core thermal-hydraulic design is pretty much straightforward. And those are from the neutron analysis point of view.

The enrichment is a standard enrichment. It's below five percent, and the fuel cycle we are going to decide in the next few weeks between two remaining options. One is for a four-year straight burn cycle, and another one is for fuel shuffling on a three-year cycle.

CHAIRMAN KRESS: It's almost impossible to get of the instability region because of this natural circulation.

MR. ORIANI: Actually, natural circulation in operation will not be terribly different from other light water reactor. It will be a higher degree of natural circulation, but it's not 40 percent as it was initially foreseen for different sizes. But two-phase natural circulation becomes important, especially in LOCA events and in those kind of accidents.

MEMBER SIEBER: This is the reactor that had the primary coolant on the shelf side of the steam generator?

MR. ORIANI: That is correct, yes. That's also the reason why the steam line break actually doesn't lead to a release of mass flow containment, because there's no mass inside the steam generators.

MEMBER SIEBER: Okay. Thank you.

MR. ORIANI: You're welcome.

MR. LEE: So as you know, the design itself is, as we mentioned, what we've written here, the information that's provided to us. Based on that, this was written.

As any other advanced reactor, we think we need to have integral as well as separate effects to validate our the model codes. And the integral ones, of course we talk about the containment-RCS coupling. The separate effects we like to see how the steam generator performs under normal as well abnormal conditions. There are a lot of design -- chemical and process industry has a lot of data on the core steam generator, but we expect that the size of this and the conditions that are going to be operating will be different, so we need to examine the performance of the steam generator under the condition that we are looking at.

MEMBER FORD: Now, as I understand it, there's other work going on on advanced light water reactors. There's a thermal-hydraulic link --

MR. LEE: Yes.

MEMBER FORD: -- on the SBWR and SWR-1000.

MR. LEE: That's correct. the ESBWR, yes, we are -- we're going to be supporting, as Farouk has mentioned earlier in the morning, the ESBWR design certification. So we are going back to the time in the early '90s when we terminated the SBWR review. We're going to start from that point and pick up and look at what the issues that we need to look into.

MEMBER FORD: And this is related to melt retention issues?

MR. LEE: No. This is -- to begin with,

we're going to be in the thermal-hydraulics related issues that we're looking into, but now we have to look into the scaling that we have done at that time and scale it back up to the higher power that the ESBWR expected to be.

MEMBER FORD: This thermal-hydraulic stuff is related to work to be done at the PUMA facility?

MR. LEE: Yes, that's correct. So we have done some work at Purdue already, so we'll use that as the starting point.

MEMBER FORD: So the fact that you don't have this in this presentation, where you're just talking about the MHR, the gas cooler reactors and the AP1000 and IRIS, does that mean it's being funded in a separate -- it's being considered in a separate program or is it within this program?

MR. ELTAWILA: As you recall, this plan was developed in February when PPMR and the AP1000 are the two programs that plants were reviewing. GE came in June of this year. So as a result of their decommission, asked several questions about what are the resources that we needed. So we itemized some resources to the Commission, and it's between now and August a decision is going to be made at the Commission whether to fund it from the existing program or request supplemental funds from Congress to address this issue.

But regardless, as I mentioned early today, since some of the heat related to gas cool reactor has been delayed, we are reprogramming some of 202 money to start doing some ESBWR work. So it's going to be funded, there is no doubt about it, but the question is will it be funded as part of the budget that approved by Congress? Because the '03 budget has been approved. So anything above that we have to go to Congress for supplementary funding.

MEMBER FORD: The reason why I ask the question is just as we go down this whole list for the plans you have, you're going to have prioritization issues and how you're going to allocate your monies, and I heard you talk about --

MR. ELTAWILA: That's correct, yes.

MEMBER FORD: -- this particular thing. Okay.

MR. LEE: And beyond this, we're also looking into CANDU Reactor as well, the ACR --

MR. ELTAWILA: Seven hundred, yes.

MR. LEE: -- 700, yes.

CHAIRMAN KRESS: Richard, could you go back to the previous slide? I had one more question on that. On your last bullet, do you actually envision a Rosa-type of an Apex-type facility for IRIS?

MR. LEE: For integral facility, that's what we're thinking about, yes.

CHAIRMAN KRESS: Yes. That one bothers me a little, because --

MR. LEE: I don't know whether --

CHAIRMAN KRESS: -- IRIS doesn't really have any ECCS like the standard. It's got all the water in there already, and the questions you had with these other facilities is can you actually get the stuff in there to the core to keep it cool? And really all you're dealing with with IRIS is what are the blowdown rates, and you don't have to have a full integral facility to determine blowdown rates. So, you know, I'm questioning whether there's a need for Westinghouse to build a full or even scaled facility with electric rods in there for an IRIS-type facility, because the design is such it looks like you don't really need that kind of detail. Am I wrong there?

MR. LEE: No, but there is a natural circulation time that the water in the containment will be circulating through the vessel and removing heat from the vessel.

CHAIRMAN KRESS: So you think --

MR. LEE: So how this very small delta p between the containment and vessel is going to actually cause the circulation and with changing in temperature and all this stuff you really need to understand how it's going to work. So although you might not have -- the blowdown itself is not the issue as much as the processes between the vessel and the containment after the LOCA itself.

MR. ELTAWILA: And, again, as Richard indicated, we really don't have enough information about the design to make a judgment at this time. But we're saying if this design is going to be radically different from what we have learned in the past, we might require a test facility. So a decision has not been made that we are going to build a facility.

CHAIRMAN KRESS: Yes. I would think about that one long and hard, because --

MR. ELTAWILA: No, I appreciate this.

MR. LEE: And I expect that we're going to use a process to look in all the phenomena before we do anything on this, even though it's not mentioned here.

And then back to the gas cool reactor, and we know that the fluid flow and heat transfer here are different because they are different medium. The code as I mentioned to you is that -- and using the TRAC-M code and then if needed we will use the FLUENT to look at more details, if there's any specific thermal-hydraulic issues that we have to look at. As you know, TRAC-M doesn't have the -- I mean, we need to put the helium, we need to put the carbon as graphite as a solid structure. For the PBMR, we need to put the spherical fuel in there. And then for the turbo-machinery, I think we do have models. We need to extend it to the different types of energy conversion device. And then on the passive heat decay removal system, whatever is going to be used, we need to modify those.

Into the severe accident arena, we are also supporting NRR in this -- supporting on this phase two design certification, and you remember that we don't expect a severe accident source term to be different between the AP1000 and the 600. I mean it's the same design, but after AP600 design certification was completed, NRC has done some more experiments at the OECD Rosecroft and Masco. We learned something from there on the in-vessel melt behavior. Those knowledge we need to be transferred for the application to the AP1000.

CHAIRMAN KRESS: As best as I recall, it was barely adequate for the AP600.

MR. LEE: That's correct, for the in-vessel retention plan.

CHAIRMAN KRESS: When you go up to 1000, you've got a lot more decay heat to deal with.

MR. LEE: Right. You have two issues. It has to do with in-vessel melt behavior, how does the heat flux distribute between the bottom head and the site on the spherical hemisphere. Then another issue has to do with the external cooling with water, and the experiment that we have done for AP600 at that time was at Penn State and USC-Santa Barbara. Those experiments showed that the critical heat flux -- the margin between the critical heat flux there's some margin there.

Now, with the higher power density now, that margin has been eroded. But we also understood that at USC-Santa Barbara, they're doing some more work by redesigning the insulation outside of the hemisphere. Essentially, what he's trying to do is to increase the critical heat flux by forcing the flow going up so try to regain some of those margins, but we haven't examined those data yet, so we have to look at those closely.

CHAIRMAN KRESS: But let me ask you a hypothetical question.

MR. LEE: Yes.

CHAIRMAN KRESS: Suppose AP1000 comes up with that this was marginal and that they don't want to take credit for it in their safety case because it's too marginal, but they say, "But we're going to do it anyway. We're going to flood the vessel anyway. We're not taking any credit for it in our safety case." Does this reopen, in your mind, questions of steam explosions?

Because now you have water there ready and you have a melt. It might go through the bottom head, and it's probably separated with the metal phase on the top where it penetrates. That's where the vessel fails first. So you've got to relatively medium pressure in there blowing out liquid metallic components into water that's already there. Does this, in your mind, raise the possibility of having to relook at steam explosions?

MR. LEE: Research is looking into -- if the in-vessel retention doesn't work and if the pressure vessel fails, we are looking into the so-called ex-vessel phenomenon. That includes the FCI, DCH, hydrogen combustions and all those.

CHAIRMAN KRESS: Do you think --

MR. LEE: But remember Westinghouse said if the in-vessel retention fails, they assume containment fails. The probability is one. That is the argument now being forwarded, yes.

CHAIRMAN KRESS: Yes, okay.

MR. LEE: In the PRA analysis.

CHAIRMAN KRESS: Yes. I remember --

MR. LEE: But, nevertheless, NRR requested us to look into the external FCI, all those issues, yes. So that's why I said at the last bullet.

For this reactor, the design is not fixed yet, so the -- I think our discussion is that the fuel doesn't look that much different to us or we said the progressions and all those core issues be that much difference between IRIS and light water reactor. That is my opinion.

CHAIRMAN KRESS: I guess I would --

MR. LEE: That's my opinion.

CHAIRMAN KRESS: -- have to question that. We've got much higher burnup, we've got all these burnable poisons in there. We've got a slower heat uprate because of the decay. You know, it took longer to get to the meltdown. I think I would expect the meltdown and fission product release processes to be considerably different from what we're used to.

MR. LEE: The higher burnup is up to around 80, so we are now looking beyond around 65, 70? So --

CHAIRMAN KRESS: Yes, but we don't even deal with 65 hardly. The database for the fission product release is obtained from around 45 gigawatt days burnup. So, yes, I would expect the meltdown and fission product release to be a lot different for IRIS.

MR. LEE: And as you can see that right before we do anything we're going to start another process to find out what we have to do for this design once the design is fixed.

Now, I have to say that the fission transfer to the primary system we need to look at it in even more detail now because of the -- the steam generator is different. So we are going through a very troubling deposition inside the core, and we don't have those models for transfer for that type of steam generator. So we expect that the fission transfer to be different.

MR. ELTAWILA: But, Tom, you heard the presentation a few months ago from CAIRSN in France, which they are planning to run some REBUS 2K test to look at high burnup fuel. So if the fission product release and the core melt progression looks any different, I know it's a very small experiment and things like that, but once we see this information we'll determine whether really the core melt progression is going to behave differently for high burnup fuel, and at that time, we'll revisit the issue. But there are some work that's going to be done in on high burnup fuel. And we are going to be part of that program.

MR. LEE: And the French may even conduct a fission product release test for up to like 75 gigawatt days per ton.

CHAIRMAN KRESS: Yes, I understand they're going to do that. Are they going to include these burnable poisons?

MR. LEE: No, not that. Now, turning back to the HTGR, as you said, the sequence fission product release transport is expected to be different. Now, we have different few designs, either spherical or an prismatic design. And there are some other reactor internal structure that we have to take into account. For example, the graphite, for example, how would the deposition of aerosols interactions with graphites? I don't know the database on that, but we're looking into it.

We have initiated MELCOR development for the HTGR. It's for the base on the TRISO fuel, so you can use a spherical one or prismatic-type reactor. As Don mentioned, the code that has been used at Oak Ridge back in the '70s until the '90s, right, there's code here. And whatever we learned from then the modeling aspect has been used for thermal-hydraulics as well as for MELCOR, because the bases start from the same point. So we are taking into account what we learned from that.

CHAIRMAN KRESS: As best I remember, GRSAC doesn't have a fission product release model.

MR. LEE: Right.

CHAIRMAN KRESS: It just has thermal-hydraulics.

MR. LEE: So we're taking the thermal-hydraulics, but they may have some other oxidation models and so forth.

CHAIRMAN KRESS: Yes, but --

MR. LEE: And we're taking those, yes. But the fission product release model is still based on the MELCOR, the root diffusions. So, basically, at early morning you mentioned about what you envision for the MELCOR code. It's the same thinking that we are pursuing.

CHAIRMAN KRESS: But that bothers me too, because the --

MR. LEE: But you need to have a database.

CHAIRMAN KRESS: Yes. You have to have a database for that. And I envision the fission product release would be driven by how rapid these TRISO pellets fail. And that's a different concept than the fission product release models in MELCOR are -- it's based on thinking that it's a diffusion process, and I don't know if failure of these TRISO pellets has anything to do with diffusion. So even the concept of using the type of models, even though they are empirical in MELCOR, is even relevant for the HTGR.

MR. LEE: But at this time, that's what we're thinking about. But you know that this --

CHAIRMAN KRESS: You're going to need a lot of data.

MR. LEE: There's a fuel PIRT that's going on that we follow very closely, because the fission gas release and so forth start from the fuel because the barrier now moves from the cladding to the fuel itself. So we are following that one. And I think beyond that there will be some more discussion on how do we model the fission product release.

MR. CARLSON: I think there are some fission product release models in the old MORECA and the newer GRSAC code, and we'll have to look at how appropriate those are for the --

CHAIRMAN KRESS: I think they were for the actual fuel if they use the cladding. The gas cool reactor fuel at one time had cladding, and I think it was -- the release models were for that, but I'm not sure.

MR. CARLSON: We're working with GRSAC right now to exercise the models that are in there as they relate to TRISO fuel.

MR. LEE: As we mentioned, just like in other programs in the fuel, in neutronics, we are looking at all the other research that are done outside of this country at the HTGR research, in specific, Germany, in Japan and IAEA. IAEA has done many -- conducted many specialist meetings on gas cool reactors, and I think we are reviewing and see what is applicable from those studies.

I think earlier they mentioned about the European Commission on the HTGR research. We are planning to participate in those, and that is in like the fuel and in all the materials, and this is another area that we are looking into. Because they want to do some fission power release in the PIE on new experiments. So --

MEMBER SIEBER: Is that $16 million for the federal program or for --

MR. LEE: I think it's --

MEMBER SIEBER: -- our share?

MR. LEE: -- $16 million that they budgeted on --

MEMBER SIEBER: Is it total program funding and then we'll pay some share of that?

MR. LEE: I don't know. The U.S. participation may not have to put any money in.

MR. ELTAWILA: The way the European Commission they will not accept money, and they don't send money outside of the European communities. So in-kind contributions. So you try to do research in the same area and exchange data.

MEMBER SIEBER: Okay.

MR. LEE: So it could be our analysis in support of reviewing the program, what type of test could be appropriate to be conducted and so forth. Those are the type of exchange.

MEMBER SIEBER: Sounds good.

MR. LEE: So, in summary, in the reactor system analysis, we tried to capitalize on whatever ready access in internationally and then we are building basically on the LWR tools that we have developed to TRAC-M and MELCOR. PARCS is a kinetics code we develop at Purdue. Don mentioned earlier the lattice physics code that we developed at Oak Ridge, which is we are doing it for the MOX, but we can modify it for HTR applications. And that is part of the scale suite of codes at the NRC used for a lot of analysis, neutronics analysis. Then we also talked about expanding our capability to address new technology issues. That is in graphite helium, high burnup fuel, up to the 80's gigawatt days for IRIS reactors. That's all.

CHAIRMAN KRESS: Any questions of Richard? I guess we've asked them all. Okay. I guess you're going to wrap things up for us, John?

MR. FLACK: Yes. My plan was to summarize briefly the other technical areas and then summarize the entire meeting, you might say, and where we go from here.

CHAIRMAN KRESS: Will that summary be a good thing to present to the full Committee?

MR. FLACK: Well, we'll have to talk about that. But what did we hear so far? So we've seen the -- we've discussed in some detail the four technical areas, framework, skills, materials and reactor systems. And now I'll quickly go through the remaining technical areas, starting with the PRA.

As we look at these other areas, there's not as a radical change to the work that we're doing now, for example in TRISO fuel where we need to understand a new technology. A lot of the work in these remaining areas build on what already has been done, and it becomes more difficult to extend it unless we have a specific design in place. We talked about this earlier about being technology neutral, and at some point you need to have a plan. And so a lot of the remaining areas are, well, we could begin to understand or look at some of the issues that we can see, but really it's difficult to move further than that until you start to get a plant and apply it, apply your thinking process to that particular design.

But in the PRA, starting with the PRA area, of course we use PRA more and more since the PRA policy statement had been put forth in 1995. And, basically, there's three areas where we're using PRA. The first one and most importantly is to support regulatory decisions, risk-informed performance-based decisions in supporting policy issue resolutions and rulemaking to help resolve safety issues and to help identify uncertainties, the extent of those uncertainties and the sources of those uncertainties and Defense In-Depth and the safety modules.

Another use of PRA is to assess licensees' PRA. We need tools to do that. To some extent, we will certainly not be in a position to do our own PRA on a design as it comes in, but there may be certain facets of a licensee's PRA that we may want to look down into detail and may decide to develop the models further for our own use and seeing if we can their results.

And then, of course, we use PRA also in our research that we do and setting what are the priorities in the research that is ongoing and what needs to be done by identifying scenarios of risk significance and so on.

The technical issues, as we see them today, and a lot of this work, by the way, has been prepared by John Ridgely and Mary Drouin, and John is here to answer any questions that you may have on them. But I summarize these issues in the following five bullets. The initiating events were advanced designs, understanding what caused these initiating events that are different than light water reactor and the database that we can call upon to help us identify those initiating events. We see this as one of the technical issues we'll have -- challenges we'll have to come to grips with.

CHAIRMAN KRESS: You will need to pin down some sort of range of frequencies for those.

MR. FLACK: Yes. If we go back to the licensing approach that Exelon had used, for example, where they tried to allocate the events into different categories -- abnormal operating events, and then they had what was considered design basis events and emergency planning events. Yes, to the extent that we can, try to identify what the likelihoods of those events are and then, of course, the subsequent source terms it might be associated with.

CHAIRMAN KRESS: Yes. I never got a chance to ask them where the got those frequencies for those events.

MR. FLACK: Well, they probably got them from the MHTGR.

CHAIRMAN KRESS: Yes. I haven't gone back to see where they got them.

MR. FLACK: Yes, right. Where did they get them from?

CHAIRMAN KRESS: But there's not a large database like we have with a lot of reactors on what initiating event frequencies might be.

MR. FLACK: Yes.

CHAIRMAN KRESS: I just don't know where they got the numbers.

MR. FLACK: Yes. Some of it, of course, is you can probably draw from light water reactors.

CHAIRMAN KRESS: That's where I think they probably got them from.

MR. FLACK: Yes. But then there's others that it would be hard to draw from without large uncertainties.

MEMBER BONACA: Will you eliminate initiating events based on the probability alone? Say that you have a concern with a possible effect that seems to be of low probability. Are you going to eliminate that?

MR. FLACK: Well, I don't think -- you know, if we were in a risk-based arena, we might do that, but it's really -- of course, any probability has a distribution, and so one needs to understand the distribution making a decision. So there's always the -- the difficulty is that even -- and it's estimated and the probability is what's the technical basis for that probability?

And this gets into things that we've heard this morning -- or this afternoon about John Muscara's presentation on how we're going to resort to probabilities where there's limited data. So you are going to end up with large uncertainties. So the question is going to become -- it's going to come about, well, okay, is there a cliff somewhere where suddenly you go a little bit further and you have this large release of radioactivity.

A lot of the research that we do tries to really probe that question, and that's why we take things to failure. There may be enough margin, but then how much more do we go before we actually get ourselves in a problem? So I think the decision is going to be a combination of things when that time comes.

But, again, it is a challenge, and of course the challenge also is in modeling these different systems, confinement versus containment, and what credit one would give for something like this. And then passive systems are always difficult to quantify, recognizing the need to identify the failure modes of those systems and so on and the applicability of the data to advance designs, which you just discussed.

And then, finally, the human performance and a multi-modular design in I&C and how does that get quantified in the context of a PRA for an advanced design, and what is the role of a human in these advanced designs? So these we see as the challenges, basically in the PRA area right at this moment.

I don't know if John Ridgely wants to add anything to that? No. Okay.

MEMBER SIEBER: I have a question about the human performance. When you talked about the concept of modular designs, do you see one control room with a bunch of reactor control panels for each module or do you see those separated somehow or another? The reason why I ask the question I once worked in a coal plant with six units run out of one control room. If one unit would get in trouble, they would rush to that unit and the other ones would float off into never-never land until something tripped.

MR. FLACK: That's a good source of information. You know, part of the work -- actually, that leads me into my second viewgraph if --

MEMBER ROSEN: Let me just make a comment on the last bullet there. There is a risk in the Safety Cross-Cut Group in the GEN IV Program. The GEN-IV Program was divided up into gas-cooled reactors, liquid metal reactors, water reactors and advanced reactors or innovative reactors. Plus it had some cross-cutting groups. One of the cross-cut groups was the Risk and Safety Cross-Cut Group, and it identified that last bullet, the human performance modeling for advanced reactors as an issue also. And it's proposing that the DOE GEN-IV Program do some research work in that area. So you might want to make a note of that and look at what's going on there.

MR. FLACK: Okay. I think Steve Arndt actually has something to say about that.

MR. ARNDT: Yes, sir. We're quite aware that we actually participated in the workshop that they held about six weeks ago to develop those recommendations. And both our Human Factors and our RSC Group were very active in that actual participation in forming those research recommendations in coordination with putting this plan together.

MEMBER ROSEN: Good. Sounds like you're tied together.

MR. FLACK: Okay. And that sets me up with the next viewgraph, which is on human factors. And, again, this is simply -- this is the question we're asking ourselves: What is the role of the operator within the context of these advanced designs.

Under the normal operations, maintaining configuration and control, as well as accident response.

And, again, relying on I&C and automatic systems to perform a lot of the functions that operators perform today is going to be somewhat challenging as to if these systems fail to function under certain conditions where you are in a multi-modular design and one module is in one state and another is in another, and everyone's focusing on the one, and the rest of these are floating out there.

One of the efforts -- activities we're planning to do initially is to just do that, to go out into other fields and see what data is out there, whether it's cold units or others and see what kind of issues do come out of these multi-control room modular-type plants in other fields. So that's something we are planning on doing.

MEMBER ROSEN: The reliance on I&C I think refers to digital I&C?

MR. FLACK: Yes.

MEMBER ROSEN: Because all these plants will be totally digital by the time we get --

MR. FLACK: Yes. Right. That's right. In fact, we have another viewgraph that's going to -- you're leading me right into the next one. These are issues. But we think of advance designs being radically different for things like TRISO fuel particles. This is actually going on today. I mean we're seeing changes in current generation and some of the work that we would be doing looking at I&C on today's plants and it could change our control rooms actually carrying us right off into what we can imagine they'll be doing for advanced reactors as well. So we sort of have a foot in both ends there.

MEMBER ROSEN: Yes. I agree with you but only in part. I think there are a lot of limitations on what the kind of changes -- the digitization, let's call it, of the current fleet is very limited, by comparison, to what I understand we're talking about here, which are --

MR. FLACK: Where we're headed.

MEMBER ROSEN: -- six plants, one control room and one screen with the operator touch-sensitive screen where the operators hits which plant do you want to know about first. Now, that's the ultimate digitization.

MR. FLACK: Yes.

MEMBER ROSEN: Then you can drill down, that, that, that, that, that, that.

MR. FLACK: Yes.

MEMBER ROSEN: That's a completely different thing than what we're used to.

MR. FLACK: The question is, of course, how do you prepare for this before it comes in the door?

MEMBER ROSEN: That's why we've left that to you.

(Laughter.)

MR. FLACK: Appreciate that.

MEMBER SIEBER: In addition to the one screen, you need six lights to tell you which unit has tripped at what time.

CHAIRMAN KRESS: In principle, I think I would rather have ten 100-megawatt modules to deal with than one 1,000-watt module.

MEMBER ROSEN: You would?

CHAIRMAN KRESS: Yes. Because --

MEMBER ROSEN: Not I.

CHAIRMAN KRESS: Well, I think I would. In the first place, I've got a lot more data because I'm looking at each 100-megawatt. I've got a lot more information about each 100 megawatts. I've got a limited dependence of one on the other. There's very few common causes I think, maybe earthquakes, maybe even tornadoes. But I can't see how one module is going to affect another one very easily. And I've just got to -- I've subdivided my problem into smaller units that I can deal with.

MEMBER ROSEN: And I would say you've multiplied your problem by ten. Instead of having a three-ring circus, you've got a ten-ring circus.

CHAIRMAN KRESS: It depends on your viewpoint.

MEMBER ROSEN: You've got three of the units in Outage 7 and the other units running of which two are at ascent, two are at descent, the other three are at stable.

MEMBER SIEBER: What we did at Beaver Valley when we faced this problem was we built a seismic glass wall through the middle of the control room and kept Unit 1 operators on one side and Unit 2 operators on the other. And the only thing you could see from one unit to the other was which ones were sweating the most.

(Laughter.)

MR. FLACK: That makes them independent.

MR. ARNDT: Actually, one of the issues that has been raised by one of your former colleagues, Professor Miller, is to basically make a ten-unit plant look like, from an operational standpoint, a one-unit plant. So it really is a combination of both the issues that are discussed here. So it's a very complicated human factors I&C issue from an operational standpoint.

MEMBER ROSEN: At South Texas, there were two identical units but with two control rooms. The units are 500 yards apart for the purpose of so they don't confuse each other.

MEMBER SIEBER: That's right. That's important.

MEMBER ROSEN: It's important. And also when one unit is in shutdown and the other on is running, you can take some manpower from the shutdown unit to help the operating unit if it gets into trouble.

MEMBER SIEBER: Well, I exaggerate the problem because really what the shift manager has to do is exercise discipline over his crew to make them pay attention to their job. And in coal plants, that sometimes didn't happen. In the nuclear plants, the discipline's pretty high.

CHAIRMAN KRESS: Well, I think it's a manpower issue.

MR. FLACK: Yes. And that leads us to that second bullet there, staffing versus in light of these multi-modular designs and how much staff are you going to have to deal with these like normal?

MEMBER LEITCH: Even with two units you get -- operators get mixed up too and have gone to the wrong unit. With ten, I would imagine that would be much more complex.

MEMBER SIEBER: We solved that with colors, but I don't even have ten colors.

MEMBER LEITCH: Yes, we did that too, with color and striping on the units and the procedures were --

MEMBER SIEBER: We painted the walls and everything.

MEMBER LEITCH: -- color-coded to correspond with the unit. But I mean there's a lot of those tricks you can do, but in spite of all those things, there's still an element of confusion.

MEMBER ROSEN: There's also bar coding now where you swipe the procedure that you're using and then you swipe the component you're on, and if they don't -- if it doesn't agree, you're in the wrong unit or you're on the wrong component. So that's one issue.

But the other issue that I think you're alluding to is the incredible numbers of people they're talking about or the very few numbers or the very few people they're talking about operating these things, because people cost 70 percent of the total for an operating plant. So if you can get that down by an order of magnitude, you've knocked a big chunk of operating costs out. But I've heard numbers that are absolutely incredible in terms of how few people they're talking about having running these plants. Is that something you're going to look at, workload, task workloads and stuff like that?

MR. FLACK: As we learn more about what their plans are, we would certainly be looking into that. What is the role of the operator in these cases with multiple plants? And reliance on I&C to do most of the job. The one thing also is this third bullet, the time that you have. Now, clearly, in many cases, you have a lot of time to react so you can get people to the site, for example. But then on the downside is could the operator do something trying to help and does something that causes -- that compromises the situation, causes an adverse situation? So that's the flipside of that. So these are issues that would need to be prepared for to deal with when they come in.

MEMBER SIEBER: There is a piece of history. The plants that were built around the time

Surrey was built may -- in the design concept of the building layouts, they would build a locker room. In our plant, our first unit had 75 lockers so each person could have a locker that was employed at the plant. When I left there, there was 1,200 people, and we had buildings with locker. So people's first estimate when they sell a power plant to the utility execs is you aren't going to need -- this plant is fail-safe and it's totally automatic, and you aren't going to need people, and it just never works out that way.

MEMBER ROSEN: It turns out paper reactors are very easy to run. Require few operators.

(Laughter.)

MEMBER SIEBER: Not one has had an accident.

MR. FLACK: Okay. And, of course, the models that need to be -- to support the PRA they do come in with and the treatment of human reliability and within the context of those models is something that is going to be a challenge.

The next viewgraph is right along the same line we've been talking about. I&C and the application reliance of advanced I&C for process control and multiple modules. Again, it's the reliability issue, the failure modes an effects analysis, the systems interactions that could occur possibly amongst the modules and the I&C may present a problem, a challenge, and then, again, the models to support the PRA in light of all that.

So at this point in time they're mostly staying engaged with what's going on in outside world and thinking ahead, but there's not too much one can do without again, having a design in and seeing exactly what it is that they're going to rely on with respect to INC. I don't know if Steve Arnot is actually the author of that section of the record.

MEMBER ROSEN: Let me ask him a question. Are we talking about continuation of the IEEE 279 requirements for separation of church and state for the protection and control? Or is this the place where we the cross the rubicon in terms of that?

MR. ARNOT: There has been some discussion both in DOE research programs and in the vendor discussions --- much more highly integrated control systems for safety/non-safety, etcetera. It's integrated in the control room and integrated some of the balance of plant systems, integrated in the switch yard. So there's a lot of issues associated with both integration across safety/non-safety and also integration of non-safety balance of plant-type issues.

That much being said, no one has come in and said we would like an exemption from these rules or we would like to change it, etcetera, either 279 or 603 or anything like that.

One of the real issues is if you're going to have a framework that is more heavily structured on risk reliability type of standpoint, how do you deal with digital system safety and things like that? And we already have in place some research programs that are looking at that both in terms of things like isolation common loop failure and those kinds as issues as well as actual coming up with numbers for digital failures, which is a non-trivial area as you are aware.

The efforts we're doing in addition to that work for the advance reactor program is looking at some of these specific issues and how that affects the ongoing work we have in place, like multi-modular issues, like some of the more highly integrated systems like things like the trade offs currently. The isolation in other issues has driven the trade offs on diagnostics versus simplicity to the simplicity standpoint. Most of the digital system retrofits we're seeing are relatively simple digital systems.

When you go to whole new digital design, and this is the first time anyone in the United States has done a completely new digital design, you get people thinking about much more complicated systems, with failure type detection systems with online diagnostic systems, things like that that complicate the systems much more highly, integrate the systems much more highly, than you would logically ever put in a retrofit. So we're planning on looking at things like that that you would see in an advance reactor that you would not see on a retrofit. That's not really a complete answer to your question, but we just don't know at this point how far they're going to go down that path.

MEMBER ROSEN: Well, the owners will decide that I think. But to some extent we need to move forward I think with digital systems. We can't stay where we are. On the other hand, where we have been I recall hearing when Y2K came about, about how robust it was in the nuclear industry because we didn't have all these digital systems. We didn't have to worry about the fact that this date glitch was going to bite us because our systems just didn't know anything about that. It was really a sobering -- if you think about that for a little bit, it told you something about the value of analog systems.

Well, we can't go there anymore, but I think we should not lose sight of the value of some of these old concepts, the separation of control and protection circuitry, and somehow manage to bring across the boundary into the new world, some of those concepts that have served us well in the past. On the other hand, in the digital systems you have a whole lot of other things you talk about, online diagnostics and fault tolerance and multiple power supplies and a whole lot of things that are of real value.

MR. ARNOT: You also have a lot of potential cost saving things like multiplex systems where you don't have to run as much wire. You have fiber optics, you have wireless sensors. You have a lot of things that vendors would see as very cost effective, but also drive you towards some of these questions that are going to be real issues.

MEMBER ROSEN: I understand there's a value in cost, but I was more interested in some of the values in safety of the new equipment. New equipment could have a lot of significant advantages in the safety area including default tolerance, for example. Diagnostics, self diagnostics, systems that turn themselves off and announce they're turning themselves off and why, and transfer control to another operating system. So there's a lot to be said for these hardened systems.

MEMBER SIEBER: Well, the conversion of an operator from an analog to a digital system is sometimes difficult. For example, when the airlines changed from analog instruments to glass cockpits, there was a lot of upset pilots because they really liked the old stuff better. On the other hand, the younger folks like the new stuff and don't like the old stuff. So there is a sort of trial for some people when they make the conversion.

MR. FLACK: Okay, another area of the plan is structural analysis section, and this was authored by Syed Ali, who is with us, Harmon Graves, and to some extent, Joe Muscara. And this area deals with the integrity of the reactor vessel and the confinement of building and structures and dealing thing with seismic, so on. The technical issues in this area, and challenges are summarized in these five bullets. Concrete, and of course, concrete having to preform at higher temperatures and then how does it age under that environment. The applicability of current industry codes and standards, the modular HTGR designs and how they're constructed and mass produced, and what kind of inspections would have to occur under those conditions. Seismic response of connected vessels. We were talking about the connected inner connections of the pipe before, how these will respond under seismic condition. And as well as graphite structures, how they will be performing under seismic conditions. Soil structure interactors. We know the modular designs are going underground and how these will behave, also again under seismic events.

CHAIRMAN KRESS: When you talk about looking at underground effects, you don't mean the whole reactor is underground. You just mean that part of it is underground.

MR. FLACK: The GTMHR is in a silo, which is a deeply embedded structure which is level with the surface. Now the original PBMR was only, I think, two thirds underground. And I don't believe that was totally underground. But these are deeply embedded structures.

CHAIRMAN KRESS: That's what you mean by underground?

MR. FLACK: Yes, that's right. Not in a cave somewhere, but I mean it's in in a silo.

MEMBER ROSEN: An AP1000 would be a deep hole.

MR. FLACK: Again, the challenge is performing risk informed inspection and service inspections for these structures throughout their lifetime. Syed, I don't know if you wanted to add anything to that at all at this point?

MR. ALI: This is Syed Ali from the staff. Just back on the soil structure interaction, I just wanted to add that most of our review expedience for the existing reactors have been for structures that are maybe partially below ground, but mostly above ground. So under an seismic event, if the majority of the structure is underground, than some of the dynamic pressures, soil pressures acting against the structure are phenomena that are non-linear and not so well understood and so we need to further develop that experience. I think that, like you said, there maybe other cases where as far various reasons, at least for the future plans that might be more underground, more sheltered than they are.

MEMBER SIEBER: Yes, there are other effects that go on there too. Shipping Port was built underground with just small percentage of its reactor plant surface of above the ground. Some of the effects were that the concrete enclosure that it was in, subject to the groundwater pressures, okay, was put in over large areas. That can be a significant force which causes cracking and leaking and all kinds of things. There's more to it than just soil liquidity and external forces.

MEMBER ROSEN: Syed, wouldn't it be true to say that there's considerable amount of experience with seismic forces on underground structures?

MR. ALI: There is, for example, for tunnels and things like that. But the sophistication and the level of analysis that you do for nuclear power plants is much higher sophistication. There is some experience on the west coast, but even there there's a lot of difference between doing a detailed, dynamic time history analysis the way we do for the structure versus some of the codes that they use on the west coast, which are superstatic analysis for seismic effects.

Plus our staff does not have the experience because they have been involved in nuclear structures which have been traditionally above ground.

MR. FLACK: Okay, thank you Syed. And that leads us then to our last area, research area, consequence analysis and basically on this one we're looking for differences in chemical forms and radionuclides that might involve from these new plant designs as well as the timing of the release and what we would might or might not need to do to MACCS to treat these differences, both in the technology of the designs and in the biological factors that result from the different chemical forms, radionuclides that would be released.

And then there's the follow on discussion which is being entertained as a possible policy issue about the length between the consequence analysis and emergency planning, for example, and the size of the EPZ. So those are some of the technical issues and challenges we see with respect to our ability to do the consequence analysis for these event plans. And Jocelyn Mitchell is with us. I don't know, Jocelyn, if you wanted to add anything to that since you had that section of the plan. So, no further questions?

CHAIRMAN KRESS: On the issue of input into MACCS, of course, there's the timing and mix of isotopes and quantity of fission products, but usually there's an energy associated with -- you have to have an input for the plume, an energy input. Is that part of what you're looking at here also?

MR. FLACK: Well, I would think that MACCS would have to deal with that at one point and the period of time over which the release will take place, for example, which could be days instead of hours.

CHAIRMAN KRESS: Do you have some criteria, for example, for gas cool reactor you concluded you couldn't get any fission products released for x number of days, you wouldn't have to have any evacuation emergency planning, you could just ad hoc? Do you have criteria like that?

MR. FLACK: That's a question of whether the Commission wants to entertain such criteria at this point. We're in severe accident space.

MR. ELTAWILA: We are planning to address that as part of the policy issue that John mentioned which will be coming out this fall, you know, so that's one of the questions.

MEMBER SIEBER: That's more of a political question --

CHAIRMAN KRESS: Well, it's political, it's defense-in-depth, it's a lot of things.

MEMBER SIEBER: Yes, but if you have an accident some people are going to take off even if they're already 50 miles from the plant.

CHAIRMAN KRESS: They're going to have ad hoc evacuation then.

MEMBER ROSEN: It seems to me what the ACRS can add to the discussion is to try to focus on the technical issue.

CHAIRMAN KRESS: Like distributing chaos?

MEMBER SIEBER: I think that's where we should restrict ourselves.

MEMBER ROSEN: Yes, because the politics are the politics and we don't have much to say --

MEMBER SIEBER: I agree with that.

CHAIRMAN KRESS: We should always focus on the technical.

MR. FLACK: That leaves me with my final view graph if there are no other questions. And this is future actions. We discussed earlier this morning and again later this afternoon about the expansion of the plant to capture these new plants coming our way, specifically the ESBWR and ACR-700 and the SWR-1000.

CHAIRMAN KRESS: I understand the ACR people finally got smart and are going to cool with light water instead of heavy water.

MR. FLACK: That's my understanding.

MEMBER ROSEN: It's a light water and heavy water machine. The advantages of both and the disadvantages of both.

MR. FLACK: That's right. So there will

be competition for the funding as Farouk had mentioned earlier which will play out over the next several months. So it's important, I think, at this point also to consider that and any letter that the ACRS writes on the subject plan comprehends completeness of the plan as well as where the scope of the plan addresses now in light of these other plans coming in.

CHAIRMAN KRESS: Do the Canadians have a PRA for their Candu reactors?

MR. FLACK: That I don't know.

MR. ELTAWILA: Not yet, but they are aware of the need to provide a PRA.

MR. CARLSON: They did provide one with Candu 3.

CHAIRMAN KRESS: Yeah, I wondered.

MEMBER ROSEN: Jack, did the last bullet refer to ACRS Members?

MR. FLACK: The last one?

MEMBER ROSEN: Yes, the last bullet.

MR. FLACK: Implement and recurrent --

MEMBER ROSEN: Trying to stay alive through this?

(Laughter.)

MR. FLACK: I don't know about that.

CHAIRMAN KRESS: It's a living document.

MR. FLACK: It means that we would certainly be flexible in consideration of other activity.

MEMBER FORD: John, in terms of the first bullet, Farouk mentioned there might be extra funding coming. Is there not a preeminent limitation of manpower?

MR. ELTAWILA: There is none in the light water technology. I think we are able to identify expertise in-house here and outside to be able to help us in light water technology. Definitely, as you are aware, there is limitation in manpower in-house and externally in the gas cooled technology. ACR, you know, it's still, although it's a light water reactor, but it's a new concept to us, the horizontal core and pressure tube and so on. So we need to educate ourselves.

So as far as the ASPWR, I don't think we have any limitation in that regard.

CHAIRMAN KRESS: For this, a lot of this research you may end up doing all your on. It's not particularly required of the licensee or the applicant, will you direct funding from Congress for that? This won't come out of fees and charges to --

MR. ELTAWILA: No, most likely. That's

the problem the Commission faced that all the research funds would be be charged to the licensee so it makes the Commission, puts the Commission in an awkward position why all this utility would pay research for gas cool reactor. So I don't think, I don't know what the Commission is going to do about requesting that additional fund, but it does not look like separate from the fee based fund.

CHAIRMAN KRESS: This sure would be a good place to have it separate.

MR. FLACK: Okay, the only other thing I wanted to mention was that we will meeting with the ACNW later this month to talk about material safety and waste renewal and then ultimately transmit the plan to the Commission this fall along with the policy issue paper that Farouk mentioned earlier. And then this document would be maintained living and work being coordinated with the user offices and maintaining it that way.

MEMBER FORD: As you see it right now, John, the plan that you submit to the Commission, how different will it be from the one we have in our books right now? For instance, will it include items coming from PERT activities, privitalization activities?

MR. FLACK: No, I don't think we'll get

too much difference from -- these other activities, I think are something we have to think about, the first bullet and the new plans that are coming our way will certainly need to be captured within the plan as best we can and transmitted to the Commission. The fact that either these light water reactors and that we're better prepared to deal with them wouldn't expect too many technology gaps that we might say that we need to fill and maintain for the long term as we do with the HTGRs, for example.

So I'm not envisioning any major differences too much with the way the plan is written now. A lot of the, I think, as we transmit the plan to the Commission, we certainly need to discuss how we plan to carry out and implement this plan over the long term and we will maintain it. And I think that will go in the SECY itself as we transmit it to the Commission. But as far as the plan is concerned, I don't see major changes to the plan from now until then.

MEMBER FORD: Okay, the reason why I asked the question is you know we committed to the Commission the research report that we have to write will be on advanced reactors. So this will be the material that we will be basing the report on. Is that a fair comment?

MR. FLACK: I think that's fair. I think we just about drained everybody we could.

MEMBER SIEBER: Just send this in.

CHAIRMAN KRESS: Yeah, just put a cover letter on it.

(Laughter.)

MEMBER ROSEN: One of the things we talked about this morning was that you had acknowledged a need to put more in it about a view of what's going on in J4.

MEMBER FORD: Will that be included in this?

MR. FLACK: Well, I think it would be more of a status of what is going on outside the group this plan originally centered on for and expand it slightly to capture these, but to recognize these other designs that are going on. Now we could incorporate that as an appendix that continuously gets updated as we get more information. I don't think there will be too much of an impact of that on the actual activities as we see them today since these are conceptual in nature and we need to follow them closely to see if there are needs, issues as they arise. But within the next few months, I don't see a major change to the plan.

MEMBER ROSEN: I just don't think you would be serving the Commission well or the public well if you didn't acknowledge all this other action going on in the world and acknowledge that, although it might not have an impact on next year's plan, it will surely have impact on the out year plans.

MEMBER FORD: Will there be any comment at all on the NEI document that's just come out?

MR. FLACK: At this point --

MEMBER FORD: Stakeholder interactions and I'm wondering if that would include that.

MR. ELTAWILA: Taking about the framework? That's already been acknowledged in the risk inform regulatory implementation plan that we sent an update to the Commission this past June and acknowledge the NEI paper and it tried to relate the NEI paper to the existing risk inform regulation and what we are planning to do for advance reactor. So it is in the EDO and once it's signed it will be available.

I'm sure that the DRA came and discussed this with you all before it went to the Commission. Or at least I hope so.

MEMBER LEITCH: In the description of the PERT process that begins on page 109 of the report, there's a six step process outlined which really describes the PERT process. I don't see clearly in that description an assessment of the viability of a particular type of reactor. Is that thought included in there?

MR. FLACK: That is generally not included as part of the PERT process when a PERT focuses on a particular technical area. I don't know, Don, do you want to comment on that?

Generally it's within a certain context. If it's HTGR, it would be focusing on fossil fuel behavior and so on.

MEMBER LEITCH: What I'm saying in assigning priorities, where does the differentiation between the likelihood of building type a verses type b verses type c. How does that enter into the prioritization process?

MR. CARLSON: I don't think that comes under PERT per se, that comes in at a different level. I think Farouk alluded to that on the seriousness of an application.

MEMBER SIEBER: If somebody sends in an application, you have to deal with that application. It's their decision and their move.

MR. FLACK: Basically you do it through pre-application.

MEMBER SIEBER: It's the way it works and you keep raising issues until they're either successful or give up.

MR. FLACK: And we saw that shift just happen with the pebble bed and now with the GTMHR, so now pebble bed has taken a back seat and GTMHR is the one we're looking closely at. So it's really, you know, a timing issue on the part of who the applicant is and when do they want to submit design certification or a licensing application.

MEMBER LEITCH: So you don't really have a good handle on the viability of a particular project, that is at that stage? In other words, are we spending our scarce dollars where we are likely to get the most payback? That's a judgmental call that we haven't really made.

MR. ELTAWILA: That's a hard question and I think the Commission deal with this issue continuously about where they are going to put these resources. And again, we will come down a Commission policy, that we are going to be working on this application. I think the Commission, anybody submit application to us we will have to consider that. And again, for other means, for example, most applications that will have more serious consideration at NRC are those are the ones that will be supported by utility which when you have utility come in concert with a vendor and say we would like to decertify this design, that will add more credibility than you have a vendor that just want to get the certification for design.

And we take that into our budget process. Not in the PERT process. The PERT process, as John and Don indicated, focus on the technical issue and where you spend your money on getting efficient product release model or on getting high temperature material or something like that.

The budget process is the one that's going to take into consideration the seriousness of the application, the support from the industry behind that application.

MR. FLACK: I should also mention that the plan itself, there are activities of the plan that are currently ongoing. It's not that we plan to do everything that's here. In fact, some of the work that's in this document is work that's going on. The question becomes which priorities and how do you prioritize future work? There's a certain level of work that needs to be maintained, for example, in graphite. A year ago, we had no one that was an expert on graphite really in the Agency. And now we are developing a person with those kinds of skills -- Shreeni was here earlier.

So we're actually doing some of this right now. And there's a certain level that one might have to say that infrastructure should be at a certain minimum, it should have a certain minimum expertise. And that would sort of take the highest priority so you'd be able to at least ask the right questions.

And then the question is is when you exercise this infrastructure, what are the activities then that you will do? And that begins, well how do we allocate our resources to do those activities? So it's like another level.

But there is this minimal level that I think the Agency needs to maintain if we're serious about gas cooled designs. And that would be an expert on all kinds of fuels to stay tuned in that area with what's going on internationally, participation with the DOE projects and so on. And things like graphite where we have somewhere here that can stay involved and engaged in that field. So when we prioritize that we don't eliminate those positions and say, well we don't need them right now. We'll go and get them later on. So I really believe there's some level we need to maintain.

MEMBER LEITCH: I had another question in the area of, the rather large area of fuels and materials. There was virtually no discussion of research activities for advanced light water reactors. Is that an issue of prioritization and some of that has been screened out? Or we just don't believe there are significant issues in fuels and materials for advanced light water reactors?

MR. CARLSON: No, the fuel section of the research plan did have a discussion of IRIS.

MEMBER LEITCH: COLLINS: Yeah, right.

MEMBER SIEBER: That has significantly different characteristics in the other light water content. I presume that the fuels in AP-600, AP-1000, BWR are pretty much the same as the concepts in current generation.

MEMBER RANSOM: Since the plan is focusing on gaps, changes, differences between now and the future.

MEMBER LEITCH: So the absence, for example, of discussion of that in the materials section, the discussion of advanced light water reactors is not, some of that has been screened out for budgetary reasons or priority reasons, but just that no significant gaps have been identified.

MR. FLACK: That's right. We are doing that work as we speak, so it wasn't trying to capture all the research we do. It's really to try to capture those gaps that we see.

CHAIRMAN KRESS: Let me ask you a technical question. Somewhere in the document I read that you need to look at critical flow at much lower pressures because the reactor depressurization, I guess it was AP-1000, I'm not even sure of that now. Could you explain what that means to me?

MR. FLACK: Critical flow?

CHAIRMAN KRESS: No, I know what critical flow is. I don't know why you're now saying it's going to occur at much lower pressures. Is that because the reactor depressurization does not take place isontropically as opposed to slow depressurization? See, I don't understand why slow depressurization and rapid depressurization gives you a lower pressure for the critical flow.

MR. FLACK: I could speculate. That could be dangerous.

MR. ELTAWILA: How about if I get back to you? I know Richard mentioned that --

CHAIRMAN KRESS: The only thing I could suspect was the rapid depressurization might not be isontropic.

MR. LEE: Yes, I think the pressure is also lower. You can get it down there faster. The data base we have, we believe that mostly in the high pressure region or the critical flow. And then the feedback from the containment also affects the flow itself. So looking at those two in combination. But it's not a critical area that will stop the AP-1000 certification. It's just completeness for the database. Off the record, I'll tell you the other reasons.

(Laughter.)

CHAIRMAN KRESS: Okay, I appreciate it. I thank you very much. How are you going to condense this into an hour and a half?

George is going to be interested in the framework. But you need to have some words there, not the full thing, but a few words. Dana is going to be interested particularly in fuels and everything else also. Bill Shack is going to be interested in materials issues and everything else. So those are the things that we want to get across to the missing members.

MEMBER SIEBER: I think in the issue of the framework, I think that's really important. And it seems like somehow or another it's not getting the attention I think it needs. So maybe talking about it again so everybody understands how important it really is.

MEMBER ROSEN: We tried to probe that this morning a little bit. But how do you decide what's a design basis accident and what's not? Or alternatively, the model of proof offered which is you don't try to decide. You just leave that aside and just say we're going to talk about risk and risk analysis and have a continuum of spectrum. I think that whole discussion, George is going to be very interested and Dana will too.

CHAIRMAN KRESS: Yeah, I think Bill will too.

MEMBER SIEBER: I agree with you, Steve. I think it still needs more working out. There is a pretty slick way to do it, I think. You know without sort of riding the line between deterministic and probabilistic analysis. And I would prefer the Agency set the tone as to how the regulation should be than have an industry group or somebody else come in and do that.

MEMBER ROSEN: Well, I think there is some good ways to do it as you suggest. But I also think we're entering into an area where there's a lot more uncertainty than there had been in the past. So I'm unlikely to say such things. The defense-in-depth margin is something at the outset turns out, you know, is crucial.

MEMBER SIEBER: You could put it on with a rational basis as based on PRA or you could put it on a deterministic basis because it feels good. And I'd rather be more --

MEMBER ROSEN: We're going to have a lot of uncertainties. We've heard about them, a lot of them, today. And so I think the discussion of how the uncertainty is dealt with with new technology and what we've been raising here is going to be of central interest to the three remaining Members who aren't here. Eight of us are here.

MR. FLACK: Okay. But although framework is only one piece of that bigger plan, there's a lot of the plan and I think it would be a disservice for me to try to summarize that plan in the short period of time. I mean, I can identify the different areas and maybe touch upon a couple. It would be tough to try to go into each subject and try to summarize each subject in an hour and a half. Plus the framework. That would be quite a challenge.

MR. ELTAWILA: If I heard, I think we need to have a presentation that covers the framework, if you will, and the materials.

MR. FLACK: You want to do that?

MR. ELTAWILA: I think we will have to do that.

MEMBER ROSEN: Well, I think some of the discussion on the neutronics was also quite useful and you can't, unless you're going to cover that in the fuel, I think you have to mention something about reactor systems analysis.

MR. FLACK: Then thermal hydraulics.

(Laughter.)

CHAIRMAN KRESS: How fast can you talk?

MEMBER ROSEN: You can talk as fast as you'd like, but you're not going to get more than about four words out before --

MR. FLACK: I think I got four vu-graphs the last time. I think that was it. It was over at that point.

MR. ELTAWILA: I will be about ten minutes each topic.

MEMBER SIEBER: Maybe the way to do it is instead of going into such great detail about what each one of these things is, is to come up with a list and say these are the projects and a one liner as to what it is you're trying to do and why it's a gap and how you're going to fill it.

CHAIRMAN KRESS: That requires making new vu-graphs between now, and I don't that's --

MEMBER SIEBER: Between now and Thursday?

CHAIRMAN KRESS: Yeah, I don't think they want to do that. I think I would select from the vu-graphs you have some way and --

MR. FLACK: Well, I could attempt to do that. I mean, we have 26 people working on the plan so I get all --

CHAIRMAN KRESS: That's up to you how you want to do it.

MR. FLACK: I can have backups and try and do that.

MEMBER SIEBER: Well, I don't we ought to make you do more work than necessary. I agree with you.

CHAIRMAN KRESS: That's one drawback with having the Subcommittee this close to the full.

MEMBER SIEBER: One thing you could do is just take the table of contents which is right near the front of the plan and make a vu-graph out of that. And that tells everybody what's in it.

CHAIRMAN KRESS: But you know, personally, I think you can probably assume that these three Members have read this. They're generally pretty good --

MR. ELTAWILA: I know Dana.

CHAIRMAN KRESS: Dana, you can be sure. George may not have had time to do it all.

MEMBER SIEBER: But he will do his part.

CHAIRMAN KRESS: He'll do his part. And Bill usually reads the things, too. You know, they won't come in not knowing anything.

MEMBER SIEBER: Yeah, they won't come in cold.

MEMBER ROSEN: You've dealt with the easy ones here.

(Laughter.)

MEMBER SIEBER: Yeah, we argue with each other.

MR. FLACK: That's why we finished on time.

CHAIRMAN KRESS: Well, you know enough now to figure out how to --

(Laughter.)

MR. FLACK: We'll put something together.

MEMBER SIEBER: I guess if I could offer

a general statement. I thought the plan was very comprehensible. Well put together. Well done.

CHAIRMAN KRESS: I agree. It was a very nice piece of work. Well done. I am going to keep it as resource document because it's got the issues in there and what people are doing at various places. I thought it was very nice.

MEMBER SIEBER: I guess the other thing that concerned me was the same thing was concerning Graham Leitch is that you've got a limited pot of money and a limited amount of resources and you've got to sort of guess which concept is going to be the hot concept of the day so that you aren't spending money on something that will never be built.

CHAIRMAN KRESS: I think they always have to have to have, they're always faced with that problem. They know how to do that.

MEMBER SIEBER: But I don't, so.

(Laughter.)

CHAIRMAN KRESS: We'll leave that up to Farouk. He knows how to do that. Well, I appreciate these very nice, very good presentations.

MR. FLACK: Thank you.

CHAIRMAN KRESS: Good work. We'll look forward to see how you can --

MR. FLACK: That we can stay below that hour and a half?

CHAIRMAN KRESS: With that I'm going to declare this Subcommittee meeting adjourned.

(Whereupon, at 5:38 p.m., the meeting was concluded.)