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

**Title:** MATERIALS & METALLURGY SUBCOMMITTEE  
MEETING (ACRS)

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TEMPLATE: ACRS/ACNW-005

**Location:** Rockville, Maryland

**Date:** Thursday, November 16, 2000

**Pages:** 1 - 109

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1 UNITED STATES OF AMERICA  
2 NUCLEAR REGULATORY COMMISSION

3 \*\*\*

4 ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

5 \*\*\*

6 MATERIALS AND METALLURGY SUBCOMMITTEE MEETING

7 CALCULATION OF NEUTRON FLUENCE DG-1053

8 \*\*\*

9 PUBLIC MEETING

10  
11 Nuclear Regulatory Commission

12 Room T2-B3

13 Two White Flint North

14 11545 Rockville Pike

15 Rockville, Maryland

16  
17 Thursday, November 16, 2000

18  
19 The above-entitled meeting commenced, pursuant to  
20 notice, at 8:33 a.m.

21  
22 MEMBERS PRESENT:

23 WILLIAM SHACK, Chairman

24 DR. THOMAS KRESS

25 DR. ROBERT SEALE

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1 ALSO PRESENT:

2 DR. NICHOLAS TSOUFANIDIS

3 MR. NOEL DUDLEY

4 DR. NILESH CHOKSHI

5 MR. BILL HOPKINS

6 DR. SHAH MALIK

7 MR. BILL JONES

8 MR. LAMBROS LOIS

9 DR. JOHN CAREW

10 MR. TUCKER WARSHAM

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

[8:33 a.m.]

CHAIRMAN SHACK: The meeting will now come to order. This is a meeting of the ACRS Subcommittee on Materials and Metallurgy. I am Dr. William Shack, Chairman of the subcommittee.

ACRS members in attendance are Thomas Kress and Robert Seale. Also in attendance is ACRS consultant, Nicholas Tsoulfanidis.

The purpose of this meeting is for the subcommittee to hear presentations by the staff concerned the proposed final Regulatory Guide on Calculation and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence.

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. Noel Dudley is the cognizant ACRS staff engineer for this meeting.

The rules for participation in today's meeting have been announced as part of this notice of this meeting previously published in the Federal Register on October 25th, 2000.

A transcript of this meeting is being kept and

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1 will be made available as stated in the Federal Register  
2 Notice.

3 It is requested that speakers first identify  
4 themselves and speak with sufficient clarity and volume so  
5 they can be readily heard.

6 We have received no written comments. A  
7 representative of Framatome requested the opportunity to  
8 make a statement at the end of the meeting.

9 The ACRS examined Draft Regulatory Guide DG-1025,  
10 Calculational and Dosimetry Methods for Determining Pressure  
11 Vessel Neutron Fluence in 1993 and requested the opportunity  
12 to review the proposed final version after public comments  
13 were reconciled.

14 Subsequently, DG-1025 evolved into DG-1053. The  
15 staff briefed the subcommittee on the status of DG-1053  
16 during its April 15th-16th, 1997 meeting. More recently,  
17 DG-1053 evolved into the final -- or into the proposed final  
18 Regulatory Guide we are reviewing today.

19 During this evolutionary process, stakeholders had  
20 opportunities to provide comments on the different versions  
21 of the Regulatory Guide. Today we will hear presentations  
22 regarding the proposed final Regulatory Guide.

23 We will now proceed with the meeting, and I call  
24 upon Dr. Nilesh Chokshi, Chief of the Materials Engineering  
25 Branch, to begin.

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1 DR. CHOKSHI: Good morning and thank you, and let  
2 me, I think as Dr. Shack mentioned, my name is Nilesh  
3 Chokshi. I am the new Branch Chief of the Materials  
4 Engineering Branch, just about three months, and OPM placed  
5 the position last month.

6 So, as such, this is my first presentation to this  
7 august body, and as it will happen, the subject matter is  
8 neutron fluence calculation and dosimetry, not the subjects  
9 I would have chosen for my first encounter. Stresses and  
10 strain is more of my language, but luckily, I have experts  
11 which are going to take you through the evolution and the  
12 technical bases -- the technical positions and the bases.

13 Then also we have an NRR expert here, so I think,  
14 you know, we are ready to explain the bases.

15 Why I am here is really to, you know, tell what we  
16 want to accomplish, why we here. And I think you already  
17 touched on some of those aspects. I think that as you  
18 pointed out, this process has been underway for quite some  
19 time, and I think we are ready here to really go, follow  
20 with the final publication of the final guide. And what we  
21 would like to do is go over the technical positions, discuss  
22 the bases for those positions and some of the implementation  
23 aspects.

24 During that process, we also want to discuss some  
25 of the major public comments received, particularly on the

1 last job for DG-1053, how we have addressed that, what  
2 changes have taken place because of those comments. And,  
3 also, describe to you when we have not -- you know, why we  
4 have chosen not to accept certain comments.

5 I am going to touch very briefly on the  
6 interactions which have taken place with the public, and I  
7 think, as both the presentations, you will see more, you  
8 know, what was the involvement, to what extent.

9 We are here to seek, starting with this  
10 subcommittee, the ACRS approval to go forward and publish  
11 the final Regulatory Guide. And I think we are the stage  
12 that the guide is ready to go forward.

13 Of course, I will just take it briefly and  
14 discuss. The guide, it basically standardizes the methods  
15 for the fluence calculations and use of the dosimetry.

16 CHAIRMAN SHACK: Excuse me. I really don't know a  
17 whole lot about this subject. But there is an awful lot of  
18 references to consensus standards that seem to cover much of  
19 this ground. Is there a reason you need your own Regulatory  
20 Guide rather than relying on consensus standards?

21 MR. LOIS: The answer is yes. I am Lambros Lois,  
22 Reactor Systems Branch. The reason is that because of the  
23 existence of a variety of methods and techniques, people  
24 have been using them to their own advantage, so to speak.  
25 In other words, they use whatever produces the best results.

1 This guide is based on --

2 CHAIRMAN SHACK: Well, that's what we want, the  
3 best results, right.

4 MR. LOIS: Well, results which satisfy specific  
5 objectives. The fundamental, the basis or the premise for  
6 this guide is the requirements of GDC-1430 and 31 which  
7 describe qualitatively what are the requirements that should  
8 be fulfilled for the materials and, therefore, for the  
9 neutron fluence. So that is the reason why we need to have  
10 a standard rule of flux.

11 As a matter of fact, there was a great deal of  
12 confusion that persists even today -- well, not confusion,  
13 but I should say created confusion as to what is the  
14 appropriate way of doing it, and that expresses the staff's  
15 intent.

16 DR. CHOKSHI: Yeah, I think the second bullet was  
17 basically that there is a wide variety of the existing  
18 methods and guidance is needed because this basically  
19 applies to a number of regulatory requirements, Appendix G  
20 and H of Part 50, 10 CFR 50.61, the whole PTS issue. So  
21 that, I think, is standardized approach, or at least a known  
22 approach will be a much better, I think, situation.

23 And you went over the brief history, you know, as  
24 you said, the initial approach was started in '93. Research  
25 received, it was only later in '92, and there have been



1 several drafts. I think when John Carew goes through that,  
2 you will see why this has taken -- how the scope has changed  
3 over the period, and there several public comments periods,  
4 you know, we have sent several drafts out for the public  
5 comments, a number of public meetings.

6 The last round of comments was on the DG-1053,  
7 which we received the comments in May and then I think since  
8 that, we have been revising the guide. And I think at this  
9 point in time the guide is ready. We have been also  
10 discussing with NRR and OGC and other people. And if  
11 everything goes according to the plan, I think we should be  
12 able to publish the guide probably next year, hopefully,  
13 sometime in the spring.

14 So what I want to do is, with this brief  
15 introduction I think what I will propose to do is --

16 CHAIRMAN SHACK: Let me ask just one other  
17 question now.

18 DR. CHOKSHI: Sure.

19 CHAIRMAN SHACK: Do you think this is going to  
20 impact those people that have sort of potential PTS  
21 problems? I mean Beaver Valley and Palisades are the ones  
22 that come to mind. You know, will the changes introduced by  
23 the guide affect those calculations?

24 DR. CHOKSHI: I will have Lambros --

25 MR. LOIS: Yes. Again, this is Lambros Lois. We

1 essentially have been working for the last year or two out  
2 of the Draft Guide. So essentially both these two plants,  
3 as well as others, have adopted the methods that are  
4 promulgated there. The only difference is that is what left  
5 to be done is just make it official.

6 DR. CHOKSHI: Yeah. I think that is important and  
7 I think my understanding is that people have been already  
8 using a number of the benchmark problems, a number of things  
9 which have been already out.

10 CHAIRMAN SHACK: This is not a --

11 DR. CHOKSHI: You know, the knowledge is out there  
12 and people are already applying it, I think. And the reason  
13 I say it is, you know, Dr. Carew is going to make a  
14 presentation, but I think I will have Bill Jones of Research  
15 and he is going to give an overview sort of, and then John  
16 is going to talk about the details of the technical  
17 positions, also how the benchmark problems and the NUREG,  
18 and then public comments. And I think in the end, we will  
19 come back and Bill will close, go over the summary and the  
20 schedule.

21 So, if there are no more questions, I think I will  
22 ask Bill to come and give his presentation.

23 MR. JONES: I am Bill Jones, and I have been the  
24 Project Manager on this Draft Guide and Reg. Guide for about  
25 a year, year-and-a-half, and so what I really want to do is

1 give you an overview before Dr. Carew gets into the details.  
2 That is really why I am here.

3 And as your slides indicate, I want to talk about  
4 a couple of things as a way of bridging into what John is  
5 going to talk about. The objectives of the Reg. Guide and  
6 then the contents of the guide. And I think if I go over  
7 the contents, it will -- the guide, it is not a small  
8 document, so my objective would be to sort of stress what is  
9 in there and sort of break it out into three parts, because  
10 that is really what is there.

11 So, our objectives were and are to provide methods  
12 and describe those methods and make them consistent for both  
13 calculation and dosimetry, for both calculation and  
14 measurement. And if a licensee chooses to use these, then  
15 these methods would satisfy our regulations.

16 And we have detailed descriptions of the fluence  
17 calculations, discrete ordinates Monte Carlo, how dosimetry  
18 measurements can be used, and the procedures for  
19 qualification and determination of uncertainty.

20 And I already talked about measurement, but there  
21 is a lot of information in there about -- there is a  
22 substantial amount of information in there about dosimetry.

23 The document itself is really -- the regulatory  
24 position is really in three parts. The neutron fluence  
25 calculational methods, and we talk a lot about that, we lay

1 that out in terms of how you would construct the problem and  
2 where you get your cross-section. We talk about neutron  
3 sources, which are pretty important to get from the outside  
4 of the core fuel to the vessel. We talk about qualification  
5 and uncertainty.

6 Okay. Part 1 is fluence calculational methods,  
7 Part 2 is fluence measurement methods. And so we talk about  
8 dosimetry. We give a lot of cautions in the dosimetry and  
9 we talk about dosimetries that can be used.

10 In the last part, in the sort of technical part is  
11 reporting. We talk about how we would expect licensees to  
12 make this information available to us, to the staff. And  
13 not part of the regulatory position, but also we talk about  
14 implementation, how the staff plans to use the information  
15 that the Draft Guide talks about.

16 So there's three parts really, there's  
17 calculational, there's measurement, and then there's  
18 reporting. So those are the three main parts, the  
19 semi-technical parts of the guide.

20 That's really all I had to say. I am really  
21 trying to outline it, lay it out for you so that John can  
22 get into the details.

23 The last slide in the smaller package talks about  
24 summary, and we will come back to that at the end of the  
25 staff presentation.

1 Do I have any questions?

2 CHAIRMAN SHACK: Is the fluence calculation that  
3 you do here consistent with what is assumed in 1.99 when you  
4 are looking at toughness variations through the wall and,  
5 you know, there is an implied fluence variation built into  
6 that?

7 MR. JONES: Lambros, do you want to --

8 MR. LOIS: Yes. This is Lambros Lois. This guide  
9 is a supplement to 1.99. 1.99 deals with the materials end  
10 of it, and this proposed guide deals with the fluence  
11 portion of that. The assumed value is what is in this  
12 guide. In other words, the quality or the rigor, or the  
13 methodology, the assumptions in 1.99 are listed in this  
14 guide.

15 CHAIRMAN SHACK: Okay. But isn't there an implied  
16 fluence variation built into 1.99 when you are looking at  
17 the throughwall variation of the fluence? At the inner  
18 wall, you start here.

19 MR. LOIS: Yes. Yes. Right.

20 MR. JONES: The calculational method that we are  
21 really talking about here, in parallel with 1.99, says, how  
22 do I get my fluence at the vessel wall? 1.99 has the  
23 exponential coastdown, whatever -- I am searching word and I  
24 can't find it. The exponential -- the reduction in the  
25 fluence as you go through the wall, that it is explicitly

1 listed in 1.99, right.

2 So, in 1.99, you need to use still that --

3 CHAIRMAN SHACK: Well, I guess that is my  
4 question. You have this rigorous method for calculating the  
5 fluence. Why do you then use a different method in 1.99?

6 MR. JONES: Well, 1.99, we are thinking about --  
7 Shah, do you want to talk about that?

8 DR. MALIK: Talk about the PTS reactivities. What  
9 you are talking about, -- this is Shah Malik.

10 MR. JONES: Attenuation, right.

11 DR. MALIK: Attenuation factor. Shah Malik,  
12 Office of Research, Materials Engineering Branch. You are  
13 talking about attenuation factor, that is an approximate  
14 exponential minus .24X there. That is an approximation  
15 which, when we do the tail -- calculation, we have found  
16 that, at least for the first quarter thickness of the  
17 vessel, that attenuation is very close or just a little less  
18 than the found from this Reg. Guide.

19 CHAIRMAN SHACK: Okay. So it is consistent?

20 DR. MALIK: It is consistent. And as you go  
21 further towards the outer surface, the attenuation factor  
22 there is I think lower than what you see here. So it is  
23 more conservative, exponential .24X is more -- minus .24X is  
24 more conservative than you find in front here.

25 MR. JONES: We have taken the attenuation and we

1 have laid the actual calculation right on top of it. And  
2 the description Shah gave is correct, I mean that is a good  
3 description. They are not inconsistent, they are not very  
4 inconsistent.

5 CHAIRMAN SHACK: Are there any more questions?  
6 Are there any more questions?

7 [No response.]

8 CHAIRMAN SHACK: And I just want to say we  
9 appreciate your time and letting us come talk to you about  
10 this. And so without trying to bridge into it and dividing  
11 the Draft Guide into three parts, I am going to introduce  
12 Dr. John Carew from Brookhaven, who has been involved in the  
13 Draft Guide since it was started.

14 DR. CAREW: I'm John Carew, and I will be  
15 discussing, I will be reviewing some of the details of the  
16 Regulatory Guide DG-1053 on Calculation and Measurement of  
17 Pressure Vessel Fluence. I will also be discussing the  
18 resolution to the comments we received from industry in May  
19 and then I will finally be discussing the NUREG report which  
20 describes the pressure vessel fluence benchmark problems.

21 Let me first note that the reactor pressure vessel  
22 fluence is required for the determination of vessel  
23 embrittlement and lifetime and the vessel fluence is used to  
24 determine the adjusted reference temperature for the  
25 nil-ductility transition, RTNDT, and also the fluence is

1 required input for the PTS Rule 50.61 for the termination of  
2 the reference temperature for PTS.

3 The problem with the fluence stems from a  
4 combination of several factors, and this includes, first of  
5 all, the neutron fluence undergoes -- and this is the key  
6 item, the problem, the neutron fluence undergoes several  
7 decades of attenuation between the core and the pressure  
8 vessel.

9 And here in the next slide we have, this is the  
10 pressure, here is the core, barrel, thermal-shield and  
11 pressure vessel, and as the neutrons propagate from the core  
12 out to the vessel inner wall, they undergo three decades of  
13 attenuation. And as shown in the next slide, this is the  
14 group 1 flux, the flux in the group right around 1 MeV. You  
15 can see the flux is basically flat. The neutron flux is  
16 basically flat in the core region and drops dramatically as  
17 it goes into the water region. There is a spectral change  
18 right in front of the steel region, the core barrel, it  
19 shifts upward, then drops again down into the spectral shift  
20 here in front of the thermal-shield in the vessel. But you  
21 can see it drops three or more than three orders of  
22 magnitude, and that is the problem.

23 As a result of this strong exponential  
24 attenuation, the calculation of the fluence is extremely  
25 sensitive to the material and geometry representation of the



1 core and vessel internals, the core and neutron source, and  
2 the transport and numerical schemes. As a result, to get an  
3 accurate prediction of the fluence, you require detailed,  
4 multi-group, multi-dimensional calculations.

5 Now, in practice, in performing these  
6 calculations, to facilitate these calculations, there are a  
7 wide range of fluence method approximations and methods that  
8 are used, and these include, for example, cross-section  
9 sets, the treatment of the core neutron source, the axial  
10 synthesis treatment and the various computer codes that have  
11 evolved over the years to simplify this problem.

12 And, in addition, because of the limited number of  
13 surveillance capsule and benchmark data, and the uncertainty  
14 in these data, it is very difficult to determine what the  
15 accuracy of these fluence predictions are to benchmark them.  
16 And this is complicated by the fact that you really need an  
17 accurate prediction of the fluence for several of the  
18 vessels because of the limited margin to the NIIRTPTS. And  
19 this is the basic problem, and this problem is addressed by  
20 the Reg. Guide which provides procedures and methods for  
21 doing measurements and calculations that determine the  
22 fluence to within an accuracy of the order of less than 20  
23 percent, which is the requirement for the PTS rule.

24 DR. SEALE: John.

25 DR. CAREW: Yes.

1 DR. SEALE: I started my career in this business  
2 doing shielding calculations, and I have always had a  
3 considerable amount of disdain for those people who look  
4 down their nose at an uncertainty of a factor of 10 in a  
5 shielding calculation, and not appreciate the fact that you  
6 have this several orders of magnitude of degradation due to  
7 the attenuation.

8 By looking back on your sketch, and I realize that  
9 is all it is, the neutron flux versus radius.

10 DR. CAREW: Right.

11 DR. SEALE: The cavity is the region beyond the  
12 outside of the core?

13 DR. CAREW: Right, that is outside the vessel.

14 DR. SEALE: Yeah, I mean outside the vessel.  
15 There is some exponential attenuation that is taking place  
16 in there.

17 DR. CAREW: Well, it is really not -- there is no  
18 material, it is a vacuum basically. There was some air in  
19 there.

20 DR. SEALE: I'm sorry, there is some --

21 DR. CAREW: Geometrical attenuation.

22 DR. SEALE: Geometric attenuation, yes.

23 DR. CAREW: Exactly, right. Yeah, and it is very  
24 slight, it is small compared to the material attenuation,  
25 but it is still there, and the calculation reflects that,

1 but on this scale you really can't see it. But you are  
2 exactly right.

3 DR. SEALE: Yeah. Yeah. Essentially maybe --

4 DR. CAREW: 1 over R squared or --

5 DR. SEALE: Yeah. Well, as a matter of fact, if  
6 you multiplied the flux by R squared --

7 DR. TSOULFANIDIS: It is not 1 over R square.  
8 Neutrons are streaming out.

9 DR. CAREW: Well, it is cylindrical geometry, you  
10 know.

11 DR. SEALE: I appreciate that. Well, it is 1 over  
12 R, I'm sorry, roughly. In the cylindrical geometry, it is  
13 pretty close.

14 But the point is that that is not exactly flat.

15 DR. CAREW: Exactly, right.

16 DR. SEALE: Okay.

17 DR. CAREW: Okay. Let's see. So now, all right,  
18 let's see. So in the following, I will be discussing the  
19 Regulatory Guide, reviewing some of the major points in the  
20 Regulatory Guide. I will be discussing how we resolve the  
21 recent May NFE comments and the benchmark problem analyses.

22 Okay. Let me start with the Regulatory Guide.  
23 The Regulatory Guide was developed by the Materials  
24 Engineering Branch of the Office of Nuclear Regulatory  
25 Research by Brookhaven National Laboratory with input from

1 NIST and from Oak Ridge.

2 The purpose of the guide was to document  
3 calculation and measurement methods for determining pressure  
4 vessel fluence that are acceptable to the NRC. The scope  
5 included vessel determination for input to the PTS rule and  
6 to the Reg. Guide 1.99 and Appendix G.

7 The Reg. Guide included a very detailed  
8 description of the fluence calculation and measurement  
9 methods, procedures for qualifying the calculations and  
10 measurements, a table of specific modeling, dosimetry  
11 qualification and reporting requirements, and it requires  
12 the calculation of the benchmark problems in NUREG-6115.

13 In calculating the fluence, the primary  
14 calculational tasks, as you might expect, or the major tasks  
15 are, first, the determination of the geometrical and  
16 material composition data. Second -- of the configuration,  
17 the vessel out through the barrel, from the core out through  
18 the barrel and downcomer into the vessel. The second step  
19 is to determine where -- how many neutrons are we producing.  
20 And that is the determination of the core neutron source,  
21 which is relatively complicated. And, finally, the  
22 propagation of a neutron source in the core out to the inner  
23 wall of the vessel. These are the three major steps in the  
24 calculation.

25 CHAIRMAN SHACK: John, how do you average that? I

1 mean, you know, the fuel is burning during -- as you  
2 rearrange the core and as you reload fuel. What averaging  
3 do you do in the time variation here?

4 DR. CAREW: Well, first of all, you have to  
5 recognize that 85 percent of the source is coming from the  
6 peripheral -- the bundles in the periphery of the core. And  
7 what you really need to know is what is the power -- well,  
8 basically, what is the power in each one of those  
9 assemblies. And you can integrate that over each cycle and  
10 determine what the power produced.

11 Then the next question is, where is the power --  
12 from which isotopes if the power being produced? And you  
13 get that from fairly -- a fairly good reading on that from  
14 the standard cell the physics people use, the core designers  
15 use in the cell calculation. They can tell you you have 50  
16 megawatts or a certain number of megawatts coming from a  
17 specific bundle, they can tell you that 50 percent is coming  
18 from the U-235, 34 percent is coming from the plutonium-239,  
19 et cetera. So you can determine which isotopes the power is  
20 coming from, and then, given that, you know what the -- you  
21 can determine, you knew what the nu over kappa is, and which  
22 it tells you how many neutrons per MeV are being produced.  
23 And then, finally, there is good data on how those neutrons  
24 are distributed in energy from the neutron spectra.

25 So, you first sum that up over the cycles. Now,

1 any point on the vessel really doesn't see one bundle, it  
2 sees several bundles, probably three or four bundles on the  
3 periphery. So have the benefit of, you know, in addition,  
4 you are adding out over many cycles, so you are not that  
5 sensitive to a given particular bundle. You may be high in  
6 one cycle, but low in the next cycle.

7 But you touched on it -- well, there is another  
8 complication in the fact that there is a gradient on the  
9 periphery of the core, the peripheral, the fuel, the pins,  
10 you know, there is a gradient on the bottom, on the outside  
11 of the core that doesn't go off abruptly like a step  
12 function, and you have to account for that also. There is a  
13 benefit for that because the fluence is using it, treating  
14 it as a step function would over-predict the fluence. So  
15 you have to account for that. And the pin powers are --  
16 those are well determined.

17 But that is an excellent question, because it  
18 turns out that one of the major uncertainties in the fluence  
19 prediction is the source. Basically, there are two  
20 dominants. In the calculation of the fluence, there are  
21 really two important uncertainties. One of them is the  
22 source. How much power is being produced in those  
23 peripheral assemblies? And there is a substantial, as you  
24 might -- as you probably understand, there is a substantial  
25 uncertainty in that prediction.

1           And, secondly, in many vessels -- in some vessels,  
2           there is some uncertainty in the inside diameter of the  
3           vessel. And because of the strong exponential attenuation  
4           of the fluence, any displacement of that vessel introduces a  
5           significant amount of uncertainty. So that is the other  
6           major uncertainty in the calculations. That's how you  
7           determine what the source is and what the powers, you have  
8           to sum that over each cycle.

9           CHAIRMAN SHACK: So the geometry is actually a  
10          major source of uncertainty.

11          DR. CAREW: Yeah, exactly, and it is because the  
12          -- the problem would go away if everything was flat.

13          Okay. Right. Now, let me go to the next slide.  
14          This slide is the -- I just might say that there are two  
15          methods that the guide allows to the calculation to be done.  
16          You can use a discrete ordinates transport method or you can  
17          use Monte Carlo. And I will just, I will start with the  
18          discrete ordinates method.

19          And, as I mentioned before, this is a flow diagram  
20          of the calculation, and the calculation really takes place  
21          by this code here, DOT, discrete ordinates transport, DOT.  
22          There are later versions of that called DORT and DOORS, but  
23          they were basically the same code. And this is the code  
24          that calculates the fluence, the transport of the neutrons  
25          from the core to the vessel.

1           Now, to do that calculation, you need, first of  
2 all, the input of the core geometry -- the system geometry,  
3 and that is fed in here from the left, the core internals  
4 vessel geometry. And then, secondly, you need to know what  
5 is in those regions, what material is in those regions, and  
6 that comes from this region, from this component here. You  
7 feed in the component material composition, which is  
8 combined with the microscopic neutron scattering cross  
9 sections. They are fed into the code and these determine  
10 the strength of attenuation in each one of the regions.

11           And then finally you need to know the source. You  
12 need to know how many neutrons are being produced in the  
13 core. And that comes from a combination of, first of all,  
14 the cycle-dependent assembly pin and powers and exposures.  
15 You need to know the exposure because, as the exposure  
16 accumulates in the bundle, you get more and more plutonium  
17 present and plutonium produces more neutrons per energy MeV  
18 and it produces a harder, faster neutron, so they propagate  
19 more readily to the vessel. And, consequently, higher  
20 exposure bundles are more of a concern because they produce  
21 a higher fluence.

22           So you need to know the exposure and then also you  
23 take the amount of neutrons, the power and exposure being  
24 produced, combine that with a spectrum, the energy  
25 distribution of those neutrons. That is fed into this code,



1 and it transports the codes out to the vessel.

2           There is one additional complication, this  
3 calculation is so complicated that actually you typically  
4 just do a planar calculation in R theta geometry, and then  
5 you do an axial calculation, and then you do a synthesis to  
6 combine then and that is the step here. So that is  
7 basically how the calculation is carried out.

8           CHAIRMAN SHACK: Is your technology robust enough  
9 that if somebody, you know, starts burning mixed oxide, that  
10 you change the inputs, obviously, but have you changed the  
11 basic technology here? Is the guide still valid?

12           DR. CAREW: As you pointed out, you change the  
13 input. The exposure would be more and, consequently --  
14 well, not just exposure, but, as I mentioned, with high  
15 exposure, you get a higher inventory of plutonium. And, as  
16 a matter of fact, after two or three cycles, the fraction of  
17 plutonium being -- the fraction of fissions in the plutonium  
18 is like 70 percent. So for high, we only put -- let me  
19 write that down, 60 percent, so with a high burnup bundle,  
20 you are getting 60 percent of your fissions in plutonium  
21 already.

22           Now, if you go to mixed oxide fuel, you probably  
23 would go even higher, but all the arithmetic and all the  
24 mechanism and all the algorithms are all the same basically.  
25 There would just be a little more plutonium.

1 DR. SEALE: It starts sooner.

2 DR. CAREW: It starts sooner, right. And so that  
3 is the basic calculational scheme. And I will just say in  
4 passing that one of the comments in the round two comments  
5 was that they wanted not only discrete ordinates capability,  
6 they wanted us to address how you do Monte Carlo  
7 calculations.

8 Go ahead.

9 CHAIRMAN SHACK: For one second. When I looked at  
10 the public comments, most of them seemed to be more on the  
11 clarification order, and then I came to the one from the  
12 professor at Penn State who said the whole thing wouldn't  
13 work for BWRs.

14 DR. CAREW: I will discuss that.

15 CHAIRMAN SHACK: Okay. You are going to discuss  
16 that.

17 DR. CAREW: Right. Right. So one of the round  
18 two comments, I guess that was in '96, was to expand the  
19 scope of the guide, and this was a substantial expansion,  
20 for a couple of reasons. First of all, at the time that it  
21 was suggested, Monte Carlo was really not being used for  
22 this calculation, for various reasons. And so it was new  
23 technology, it had never been accepted by the NRC really,  
24 but we expanded the scope and have included Monte Carlo in  
25 both the Regulatory Guide and also in the benchmark

1 problems.

2 But, in any case, the Monte Carlo capability is  
3 really not very much different than the discrete ordinates.  
4 It is basically the same. The only thing different is this  
5 code here, the transport of the neutrons from the core to  
6 the vessel is carried out, instead of a deterministic  
7 discrete ordinates space energy mesh type of calculation, it  
8 is carried out in a statistical manner where neutrons are  
9 started off and their trajectories are followed as they go  
10 from the core out through the various scattering events, out  
11 to the vessel inner wall, and the tallies are summed and an  
12 estimate of the fluence is determined.

13 The advantage, of course, is that all the surfaces  
14 in the problem are modeled exactly and the geometry is a  
15 true, high fidelity, exact fidelity, basically,  
16 representation of the geometry. Of course, the complication  
17 is that because of this attenuation in the core, that you  
18 are dropping by three decades, it takes -- you have to start  
19 off a thousand neutrons in the core before one will  
20 eventually arrive in the vessel. They all disappear before  
21 they get there, which means the statistics, if you run a  
22 calculation, the variants in your edit will be you will  
23 never get any neutrons. There will be so few neutrons that  
24 your statistics are very, very poor, and that is the  
25 complication. So you win, but you also lose.

1           So, anyway, this is basically -- this has all been  
2 included in the guide and in the benchmark problems.

3           DR. TSOULFANIDIS: John

4           DR. CAREW: Yes.

5           DR. TSOULFANIDIS: Nick Tsoulfanidis, ACRS  
6 consultant. You might mention one advantage of Monte Carlo  
7 is you may have continuous energy cross sections, however,  
8 whatever uncertainty you have the source, it is the same for  
9 both methods.

10          DR. CAREW: Exactly. Right. Yeah. That's a good  
11 point. One thing I didn't mention, the advantage of the  
12 Monte Carlo is that not only do you get a sense of doing it  
13 statistically, you can include the exact cross sections  
14 continuously. So if you have an event, you can sample from  
15 the energy and find out what the energy was and go look up  
16 the cross sections at that specific energy, where in a  
17 discrete ordinates calculation, you have to assume that you  
18 break the energy range into discrete intervals.

19          And it turns out that that approximation is not --  
20 with the number of groups that we use, we can get a pretty  
21 good idea of what the error is by going from a large number  
22 of groups down to smaller groups and see how the error, how  
23 it changes.

24          So the technology is well developed and we have  
25 got -- we know the values, or we know where all the

1 approximations are.

2           Okay. The next item I would like to discuss is  
3 the qualification. We have these methods, and now, as  
4 required by Appendix B of 10 CFR 50, the methods must be  
5 qualified. And how do we assure that they are valid and  
6 accurate?

7           The guide requires that this take place in two  
8 steps basically. The first step would be do an analytic  
9 determination of the uncertainty. And that means we take  
10 the computer code and we perform some numerical sensitivity  
11 calculations where we perturb each one of the input  
12 parameters and see what the change in the edit is, the  
13 fluence is. And once we know what all the sensitivities  
14 are, and, of course, we would be focused on the vessel  
15 diameter, what the sensitivity to the vessel diameter change  
16 is, and, of course, what the change in the source is, what  
17 the effect is. And there is other uncertainty as well, but  
18 they are the major ones.

19           So we determine what the sensitivity is, and then,  
20 using that sensitivity, we combine that with estimates of  
21 what the source uncertainty would be and what the  
22 sensitivity -- what we think the vessel diameter uncertainty  
23 is. And I might add that for some vessels we have a lot of  
24 measurement data, and we have a very good idea what the  
25 uncertainty in that vessel, you know, they go through the

1 vessel, around the circumference of the vessel and take  
2 various measurements, and we have looked at those, and you  
3 have a lot of data. You can get a mean value, you can get a  
4 standard deviation. You can get an idea of what the  
5 uncertainty of that vessel diameter is. Other vessels, we  
6 have very little data. So it varies from plant to plant.

7 But if we have a lot of good data, there is a very  
8 good indication of what the uncertainty would be. And so  
9 this is one technique.

10 But we have to recognize there are some situations  
11 where we have very little data and this would not provide a  
12 good estimator of what the fluence uncertainty is. So we  
13 have to do more than one -- have more than one path.

14 And this other path is basically comparing  
15 predictions to benchmarks. And there's several types of  
16 benchmarks. We have some plants have extensive operating  
17 dosimetry surveillance capsule data. So, for those plants,  
18 we would be looking at dosimetry data.

19 Also, there are available some pressure vessel  
20 simulator experiments, the PCA and other experiments that  
21 have been done, that also provide extensive dosimetry and  
22 good measurements, so that is another path.

23 And then finally we have a benchmark problem,  
24 NUREG-6115, which provides a definition problem, a well  
25 defined, complete problem to calculate and reference

1 solution.

2 So we would go through this qualification  
3 procedure and we would determine what the uncertainty would  
4 be, and that is the qualification path.

5 Now, for the PTS rule, we should show that the  
6 uncertainty has to be less than 20 percent. Now, in the  
7 next slide. Now this is a figure that was suggested by one  
8 of the commenters from Bechtel, actually Bill Hopkins. And  
9 what this does, in the guide, the PTS rule requires an  
10 uncertainty of 20 percent. And what do we do if the  
11 uncertainty is greater than -- what does a licensee do if  
12 the uncertainty is greater than 20 percent?

13 Well, this diagram shows clearly, describes how we  
14 address that situation. If the uncertainty evaluation, if  
15 the uncertainty is less than 20 percent, we just proceed and  
16 we use the calculated value and apply, if there is a bias  
17 that we want to apply, we can just multiply by the bias, and  
18 we get the result.

19 The complication occurs if the uncertainty is  
20 greater than -- well, the uncertainty is greater than 30  
21 percent, the guide is no longer applicable. This would  
22 require a case-specific review. On the other hand, if the  
23 uncertainty is between 20 and 30 percent, we have the option  
24 where you can reduce the fluence value by an amount that  
25 would preserve the probability -- it would ensure that the

1 probability of an under-prediction is not increased. So in  
2 this case there is a penalty applied to the fluence.

3 DR. KRESS: What is the basis for the selection of  
4 those percentage acceptance values?

5 DR. CAREW: Which, the 20 percent?

6 DR. KRESS: Any one of them.

7 DR. CAREW: Well, okay, the 20 percent is part of  
8 the -- is what was assumed in determining the PTS criteria  
9 rule. They allocated 20 percent uncertainty for the  
10 fluence, so that is where the 20 percent comes from.

11 Now, the 30 percent is a number that we think this  
12 is a reasonable -- if someone has a 30 percent uncertainty,  
13 this is a reasonable uncertainty. It may not be that  
14 surprising, and, therefore, we allow them to use that  
15 calculation, but they must -- the value must be reduced.  
16 The value of the fluence must be reduced by an amount such  
17 that the probability of an under-prediction is not  
18 increased. And then 30 percent, above 30 percent, we feel  
19 that that calculation really requires a special review, it  
20 is outside the scope of the guide.

21 MR. LOIS: John. This is Lambros Lois again. It  
22 is rather of historical significance. Way back in the early  
23 '80s when we were putting together 10 CFR 50.61 with the PTS  
24 rule, we were required to have -- to come up with an  
25 uncertainty. At that time, both calculational tools and



1 measurements were not -- measurement database was not  
2 available. So we utilized, actually, it was John who did  
3 that, utilized sensitivity calculations, and we concluded  
4 that 20 percent would be a reasonable uncertainty.

5 That was folded into the uncertainty or in the  
6 penalty, if you wish, term on 50.61, on 10 CFR 50.61, and  
7 that is where it stayed and ever since has been part of the  
8 calculation. And nowadays both databases are wider and have  
9 more data, and the calculation techniques are accurate. So  
10 we can do better, but because it was incorporated in the  
11 original 50.61, it still stays there. So that is the reason  
12 why it is 20 percent.

13 DR. CAREW: Okay. All right. Let's see. The  
14 next slide is the measurements and then, let's see. Okay.

15 So, in summary, --

16 CHAIRMAN SHACK: A question.

17 DR. CAREW: Go ahead.

18 CHAIRMAN SHACK: If you can do better, do you get  
19 any credit?

20 MR. LOIS: In the uncertainty, you can do better,  
21 yes. You get credit automatically because you have a  
22 smaller uncertainty. Now, unfortunately, the interns of the  
23 penalty or -- you don't, because it has to be folded with  
24 the materials and that is a mess. I mean, you know, it is  
25 very difficult to do that.

1 DR. TSOULFANIDIS: What is the basis for taking  
2 the second step, the 30 percent, and now saying if it is 20  
3 and one treatment 20 or less and one treatment 20 and above?

4 MR. LOIS: The gentleman who proposed that, and we  
5 have adopted it, is sitting in the back there, Bill Hopkins.  
6 It is just an intuitive number, just an educated guess. You  
7 feel that the 30 percent is way too out, so we don't want to  
8 continue with that calculation. There is no specific  
9 technical reason for that, like the 20 percent.

10 DR. CAREW: But we ensure, if they are in the  
11 range from 20 to 30, that the probability of an  
12 under-prediction of a fluence is maintained. So we apply a  
13 penalty to ensure that when you are in that range, that  
14 things are not degenerating.

15 Okay. In summary, the Regulatory Guide provides a  
16 best estimate rather than a bounding fluence. In other  
17 words, all the assumptions that go into the Reg. Guide were  
18 carefully made so that it is a best estimate, we are not  
19 doing any bounding calculations. If the guide is followed,  
20 the accuracy should be less than 20 percent 1 sigma, and the  
21 energy range is from 15 MeV down to .1 MeV. The  
22 qualification is by benchmarking and uncertainty analysis.

23 The applicability of the guide includes -- well,  
24 first of all, it provides input for Appendix G and Reg.  
25 Guide 1.99, the PTS rule. It is applicable to both PWR and

1 BWR core vessel geometries and fuel designs. I might add  
2 that initially, back in -- we did the 1025, the initial Reg.  
3 Guide was not really applicable to BWRs, but in the round  
4 two questions in '96, we were asked to include that, and  
5 that, again, was a substantial increase in the scope of the  
6 guide. But that has been included. So now we are  
7 applicable to both BWR and BWR cores and fuel designs. And,  
8 importantly, the guide is also applicable to those core  
9 designs that are constructed for fuel -- vessel fluence  
10 reduction, such as the low leakage cores, the partial link  
11 shield assembly cores and the life extension calculations,  
12 and also the mixed oxide fuel, now that you mention that.

13 I was going to review the status of the guide.  
14 The initial release was in 1993. At that time we had the  
15 ACRS subcommittee and committee meetings. We met with the  
16 CRGR. We released the guide for comment. We had a set of  
17 round one comments that were evaluated and incorporated in  
18 the guide.

19 We had a follow-up meeting with industry in  
20 September 18th, '96 where we reviewed the comments and the  
21 resolution. At this meeting, I mentioned there were several  
22 changes in the scope of the guide. The Monte Carlo was  
23 added to both the guide and the NUREG problems report, and  
24 also the BWR was incorporated.

25 In September, and then in September '99, a year

1     ago last September, we met again with industry. At this  
2     time industry requested that we provide the resolution of  
3     comments document which provides the basis for the  
4     resolution of all our previous round one and round two  
5     comments.

6             We provided that to the stakeholders and industry  
7     in March 2000, and we received the industry comments in May  
8     2000. And we completed the evaluation of these comments in  
9     August and have incorporated all the comments into the  
10    guide. So the guide, as it stands today, incorporates all  
11    the latest comments.

12            DR. KRESS: What does that mean?

13            DR. CAREW: Excuse me. Go ahead.

14            DR. KRESS: When you say incorporates all the  
15    comments, does that mean you looked at them and decided  
16    whether it is valid?

17            DR. CAREW: Right. And I will go into that in  
18    detail. I will discuss how we did that.

19            DR. KRESS: Okay.

20            DR. CAREW: And we intend, or we hope to intend,  
21    or we expect to release the guide in early 2001.

22            Okay. Let's see. Now, I will get into the  
23    resolution of comments. Let's see. We received comments  
24    from the Nuclear Energy Institute, Penn State University,  
25    and Bechtel Power, Bill Hopkins, and an organization called

1 Don't Waste Michigan. This is a small organization -- I am  
2 not so sure it is small, but it is an organization that is  
3 focused on one specific reactor.

4 MR. JONES: I need to interject one thing here.  
5 The Bechtel Power Corporation, those comments were received  
6 informally. They were reviewed to the same degree and  
7 treated the same. And, in fact, John mentioned that the  
8 figure that was incorporated due to those comments, you  
9 didn't get those in your package because they were submitted  
10 informally. I needed to point that out to you at this  
11 point. Excuse the interruption.

12 DR. CAREW: Okay. The comments concerned editing,  
13 organization, methods and qualification. The comments  
14 included recommendations to both tighten and relax  
15 requirements. Okay. And the resulting changes and  
16 additions have been included in the latest version of the  
17 guide.

18 I didn't want to go -- it is really unwieldy and  
19 not necessary to go through all the comments, but I did go  
20 to the effort of kind of classifying them, and to give you a  
21 flavor of what they were like, which is probably pretty  
22 meaningful.

23 Of all the comments, 50 percent were requirements  
24 or requests to update or add references. Actually, we had  
25 one case where someone wanted to delete a reference. We had

1 25 percent of the comments were to change the wording. The  
2 wording wasn't quite right or whatever. 26 percent of the  
3 comments were they wanted us to clarify certain points. It  
4 wasn't really clear, you know, there was some ambiguity what  
5 we were saying.

6 CHAIRMAN SHACK: Which comments are we talking  
7 about now, the earlier comments or the most recent comments?

8 DR. CAREW: These are the most -- yeah, these are  
9 the most recent comments, I guess. We had several -- round  
10 one and round two were first, and we resolved all those  
11 comments, or we thought we had resolved those. I think we  
12 resolved those comments, but industry asked us for this  
13 resolution of comments document, which had how we resolved  
14 each comment and what the basis of the resolution was. And  
15 we provided that to industry and then they commented on that  
16 document and also made new comments.

17 DR. SEALE: That's what this is.

18 DR. CAREW: And that is what this is. This is the  
19 last set of comments, which includes comments on the  
20 resolution of the previous comments, plus the new comments.

21 DR. TSOULFANIDIS: These were essentially received  
22 in '99.

23 DR. CAREW: These were all May '99 comments,  
24 right. And this is the sum, they went back and looked at  
25 all the resolution of our previous comments and the new

1 comments, and made new comments which included that summary.

2 CHAIRMAN SHACK: These are May 2000 comments?

3 DR. CAREW: May 2000, right. But they encompass,  
4 basically, since in March -- yeah, March 2000, we provided  
5 all the old comments in the resolution, and we said, okay,  
6 now give us all your new comments, any comments you have.  
7 So these were all the outstanding comments, up to -- going  
8 back to day one.

9 MR. JONES: Let me interrupt you. The meeting  
10 that we had a year ago, September '99, we had made available  
11 the NUREG-6115 and the Draft Guide, and we had a meeting  
12 with industry. And that was the first time they had seen it  
13 for a while. So we actually solicited comments, we asked  
14 them to give us comments. And at that meeting they asked  
15 for the previous resolution of comments document, and so  
16 everything John has been talking about is for comments  
17 received this year.

18 DR. CAREW: So, okay, and some of these comments  
19 did address -- concern the earlier comments. Okay. And 26  
20 percent were clarification where we had said things and they  
21 wanted them to be clarified. And then some of them asked  
22 for additional guidance, we didn't give them enough. They  
23 wanted to be told exactly how to do things, more detail on  
24 how to do things, and that was 9 percent. And there were  
25 some typographical errors. And about 15, 14 percent were

1 actual technical issues.

2           Okay. Now, what I have done is I have gone  
3 through all those comments and picked out what -- well,  
4 before we do that, let me give you our approach to resolving  
5 the comments. First of all, all the comments were  
6 thoroughly, absolutely thoroughly evaluated for possible  
7 inclusion. We looked at every comment in detail.

8           And we then held the comments up to these  
9 criteria. We said for inclusion in the guide, we want this  
10 comment to be consistent with the scope and the purpose of  
11 the guide. It has got to be a technically valid comment, it  
12 has got to be technically valid. It has got to be a  
13 significant portion of the fluence determination, because we  
14 have gone into a lot of detail already and it just -- it had  
15 to be something significant.

16           It had to be consistent with presently accepted  
17 methods. If someone proposed something new, some new  
18 technique and it hadn't been reviewed or wasn't accepted, it  
19 wouldn't go in, because this is a guide that includes the  
20 methods that are acceptable to the NRC staff. So new,  
21 unaccepted methods would not be included. And the level of  
22 detail should not be overly prescriptive. There should be  
23 some wiggle room and some flexibility for the analyst to  
24 address his plan and treat items that may not be, you know,  
25 included, foreseen in the guide. So there has to be some



1 flexibility in the guide.

2 Okay. So, now the comments -- this was the  
3 response, the response and the evaluation of the comments  
4 were based on a team consensus.

5 DR. TSOULFANIDIS: Who was the team?

6 DR. CAREW: Well, the team actually evolved. When  
7 we first started we had people, we had NIST, we had Jim  
8 Grundl and Dale McGary from NIST and a statistician from  
9 NIST, I forget his name. Do you know him, Graham? In any  
10 case, we had a statistician from NIST. Then we had, from  
11 Oak Ridge we had Dick Merker, Frank Kam, and Igor Renic.  
12 And I then I guess that is it.

13 Now, more recently, this has taken place over  
14 several years and some people have retired and the team has  
15 basically, the last set of comments, the team has been  
16 basically myself, Bill Jones and Lambros.

17 The resulting changes and additions to the guide  
18 have been incorporated into the latest version of the guide.

19 Okay. Let's see. Okay. All right. Now, what I  
20 have done is I have gone through all the comments, and I  
21 picked out -- I didn't want to bore you with all the  
22 comments, but I picked out what I thought were the most  
23 significant and important comments. Now, I would be very  
24 willing to answer any questions on any of the comments we  
25 haven't identified after I go through this. But let me

1 first start by going through the comments I have selected  
2 and maybe I have got the ones you want to see.

3 First of all, there were some general comments  
4 made by NEI and the first one was that the final version of  
5 the NUREG report on benchmark problems should be released.  
6 Now, as Bill Jones just mentioned, that we have, at the  
7 September '99 meeting with industry, we released a draft  
8 copy of that report. And there were comments on that report  
9 in this set of comments which we are addressing. And I  
10 might add, there was no major change suggested to the guide,  
11 to the NUREG report.

12 But, in any case, we are working on this,  
13 finalizing the guide -- finalizing this report. Now, we  
14 expect to release this report in early calendar 2001.

15 The second comment was that NEI suggested that we  
16 have a round robin between industry contractors -- between  
17 NRC contractors and industry participants, doing  
18 calculations of a standard problem, the benchmark problem.  
19 Our response to that is that that is really outside the  
20 scope of the guide. The guide is intended to state what are  
21 accepted methods and describe them.

22 In addition, I mean the guide provides a highly  
23 detailed guidance on how to do calculations and measurements  
24 that are accepted and that can be input to Appendix G, 10  
25 CFR 50.61, and the application of these methods appears in

1 several of the references in the guide. In addition, the  
2 NUREG report presents several more applications of the  
3 guide's methods.

4 DR. KRESS: It seems like, though, if you had such  
5 a round robin, that it would be a good indicator of the  
6 potential variability of the results that you would get from  
7 user variability, and that might be of interest to NRC as  
8 something -- you know, it doesn't have to be put into the  
9 guide, but it sounds like it would be a good thing to do.

10 DR. CAREW: I am going to discuss that, I am going  
11 to discuss the NUREG report. And you will see, when we do  
12 those calculations, that if someone takes that problem and  
13 uses the methods in the guide, for example, the methods that  
14 are used for Palisades and Beaver Valley, whatever, uses the  
15 latest libraries and the current state of the art codes,  
16 they would get results that are very, very -- and we have  
17 done that. You will see --

18 DR. KRESS: I had in mind not using the benchmark  
19 problem, but to take a reactor core, and say this is what  
20 the core looks like.

21 DR. CAREW: Yeah.

22 DR. KRESS: And you go do it for this core and let  
23 everybody use the same core. But they have to prepare the  
24 right input and prepare everything and see what variation in  
25 results you get there.

1 DR. CAREW: Right. Well, now, let me just say  
2 this. That is how the benchmark problem is intended to be  
3 used and the licensees, when they evaluate their methods are  
4 intended -- they are supposed to go out and take that NUREG  
5 problem and do exactly what you said, take that core that is  
6 well defined, calculate it and see how they do, and submit  
7 that into NRR. And they are going to -- NRR will look at  
8 the results and say these look great and this will be the  
9 basis. And I will discuss in this more detail. But these  
10 look great, and that will be a large part, or a part of  
11 their licensee's approval of their methods.

12 To do the round robin, you would be doing exactly  
13 that and everyone would be doing it together. Well,  
14 actually, now that I think about it, that may not be such a  
15 good idea because it allows people to -- well, I guess it is  
16 good for the industry and everything.

17 But just let me say this, that there is -- we have  
18 just recently got a submittal where one of the licensees has  
19 done that. They have taken the problem and gone off and  
20 calculated and submitted that as part of their submittal.  
21 So that type of thing, the activity is going on. Maybe wait  
22 till the end and we will discuss it. After I go through the  
23 benchmark problems, we can talk about this, you can bring it  
24 up again.

25 MR. LOIS: John.

1 DR. CAREW: Okay. Lambros, you were going to say  
2 something.

3 MR. LOIS: Yes. To be more specific, yes, we did  
4 have and the other day, so the development of the  
5 methodology, we didn't have a round robin. And that was  
6 from Pacific Northwest in the laboratory where we did, the  
7 NRC funded a sizable dosimetry and calculational,  
8 consequently, calculational project.

9 At that time we did have a round robin  
10 calculation. In fact, we invited about 10 participants from  
11 national laboratories and the industry, and I do recall that  
12 we plotted the results and there was a factor of 3 top to  
13 bottom variation. And then we realized the enormity and the  
14 significance of the project, but, really, we did not know we  
15 could not reliably calculate fluences or even measure them  
16 to that effect.

17 That project, which lasted for several years,  
18 formed the background of what we have now. So such  
19 measurement and calculations have been part of the  
20 historical development of this guide.

21 DR. CAREW: And that experiment, that round robin  
22 was for the pool critical assembly benchmark experiment.

23 Okay. So these are the first two general comments  
24 that we had. And then I will go through some of the  
25 specific comments. The first comment is that the industry

1 went back and looked at how we resolved the earlier comments  
2 and they made the observation that some of the responses to  
3 those earlier comments provided valuable insight and should  
4 be included in the guide. And went back and we agreed that  
5 some of these comments did actually provide valuable  
6 insights, but we also saw that some of them had already been  
7 -- we recognized that earlier had incorporated some of them  
8 already.

9           There were others that we saw and said, yes, these  
10 are good, and in the next version we have incorporated them.  
11 And then there were some that were outside the scope of the  
12 guide and we didn't think it would be appropriate to put  
13 them in. So we went back and looked at that and  
14 incorporated the ones that hadn't been incorporated already.

15           The next comment, there were several -- several  
16 commenters identified ASTM standards. For example, the ASTM  
17 standard which characterizes the neutron exposure of iron in  
18 terms of displacements per atom. We incorporated that  
19 standard. There was a standard on testing and benchmarking,  
20 we have incorporated that. The selection of dosimetry cross  
21 sections, and also there was one I left out here on the  
22 least squares adjustment methodology, that standard has also  
23 been incorporated. So the ASTM standards that were  
24 relevant, we have incorporated.

25           Let's see. The next comment was when the Monte

1 Carlo -- in the Monte Carlo analysis, you have to set up  
2 kind of a bin to record, for each neutron, the contribution  
3 to the dosimeter response. And the danger is the cross  
4 sections in these, for the dosimeters are thresholded --  
5 have threshold cross sections, and if the bin is too wide,  
6 you won't get an accurate, because the fluence may be large  
7 down here in a region where the dosimeter cross section is  
8 small, and you won't do the integration correctly unless you  
9 have an appropriate bin structure.

10 So that was pointed out and that was a good  
11 comment, and we have incorporated that in doing the Monte  
12 Carlo calculation, you must make sure that the bin structure  
13 is fine enough to ensure an accurate integration over the  
14 cross section. So that has been included.

15 Another comment was that in the guide, as you  
16 might expect, that the Monte Carlo calculation, the major  
17 weakness in the Monte Carlo calculation is the statistics,  
18 the variance, and especially in these types of calculation  
19 where you have this strong attenuation, you have to make  
20 sure that -- and, typically, you can't do that. You can't  
21 do this calculation with Monte Carlo unless somehow you have  
22 a technique to increase -- reduce the variance, because if  
23 you start the neutrons off, you only get 1 per 1,000 hits  
24 the vessel and the statistics are very poor. So you have to  
25 some kind of a scheme which is going to reduce that

1 variance. And there is variance schemes that people use.

2 And in any case, because of this, we recognize  
3 that we should put in some kind of criteria for people so  
4 that when they get a fluence estimate, they will know that  
5 it is reliable. So we put in five statistical criteria and  
6 the commenter noted that those criteria are really specific  
7 to MCNP. And so what we did is we suggested that these be  
8 set as a minimum set. And so we have changed the wording so  
9 that the criteria we have included there is a representative  
10 set, it is not a definite set. It is a representative set  
11 and not a minimum set, so that is how we have corrected  
12 that.

13 The next comment was -- this is a little bit  
14 tricky. When we do the benchmarking, we basically have  
15 three estimates of what the uncertainty is. We have an  
16 analytic estimate of what the uncertainty is, an estimate  
17 due to the plant dosimetry, and then we have an estimate  
18 based on comparisons to the simulator like the PCA. So  
19 there is three values. We have three independent estimates  
20 of what the uncertainty is and the guide was initially  
21 written so that we let the user assign a weighting to those  
22 based on what he thinks is the best number, and they asked  
23 us for more guidance.

24 Well, we recognize, first of all, that because the  
25 weighting of the analytic estimates depends on the details



1 of the specific application, it is not really possible to  
2 specify a practical and generically valid prescription for  
3 determining the weights. It is really -- it would be  
4 unwieldy to put in the guide.

5           So what we have done is we have given an example,  
6 and we say that if you have a case where the source  
7 uncertainty is well known and the vessel diameter  
8 uncertainty is well known, the analytic uncertainty analysis  
9 will provide a good estimate of what the uncertainty would  
10 be and you can increase the weighting, say, from .3 to .5.  
11 And then, in addition, if you have -- if the measurement  
12 data, the dosimetry data is good, so, for example, you have  
13 10 data points and they all have an accuracy of 5 percent,  
14 that estimate should be reliable and you can increase the  
15 weighting of that to, say, .3. And, consequently, the  
16 simulator weight would be .2.

17           So we have given an example that would indicate,  
18 you know, what you have to consider. You know, look at the  
19 uncertainty analysis and ask yourself how good is that.  
20 Look at the dosimetry, if you have a lot of good  
21 measurements that are really highly reliable, that is a good  
22 estimate and maybe the simulator is not so good.

23           So rather than try to have some kind of a generic  
24 prescription that would be unwieldy and wouldn't be  
25 appropriate for the guide, we have put this example in. I

1 think that is about as far as we can go.

2 All right. Anyway, any comments?

3 [No response.]

4 DR. CAREW: The next comment was additional  
5 guidance on how the calculational benchmark should be used.  
6 We initially had -- we are going to use it to determine, to  
7 actually determine the uncertainty, make a quantitative  
8 estimate of the uncertainty. And the commenter suggests,  
9 why don't we make this into a go/no-go test? Well, we  
10 actually thought that was a pretty good idea and we have  
11 changed the guide. So the calculation of the NUREG  
12 benchmark problems will be basically a go/no-go test. You  
13 do the calculations. If they look at them, and they look  
14 reasonable, you are getting close agreement, you get a go.  
15 If they don't, you have to go back and look at your methods  
16 and revise -- either explain why you are getting large  
17 differences or revise your methods.

18 And we expect, as you will see, we expect the  
19 benchmark problems, since the problem is completely defined,  
20 very little source uncertainties or geometry uncertainties,  
21 you should get a very good, a very close agreement. And  
22 that is what we are -- okay.

23 The next comment was, while the guide provides  
24 guidance on what agreement we should expect when you compare  
25 integrated quantities -- integral quantities, there is no

1 guidance on when you compare group-wise quantities, what  
2 type of agreement you should get. And that is true, we  
3 didn't give any guidance, and, therefore, we have removed  
4 that requirement. We no longer require them to compare  
5 group-wise quantities.

6 Another comment was we didn't define what a bias  
7 is or we didn't define bias or uncertainty in the guide.  
8 And so we have added a reference for the term bias.

9 The next comment was the level of detail required  
10 for benchmark analysis wasn't sufficient or we needed more  
11 data. And what we did is -- and let me point out that the  
12 benchmarks require a comparison to a simulator, which would  
13 be the pool critical assembly experiment, for example, the  
14 operating reactor dosimetry measurements or the NUREG  
15 report. I would just say first that we have already  
16 included several examples of simulator experiments, the PCA  
17 and the Venus. And in response to this comment, we have  
18 added some more references. So we have beefed up this area  
19 in response to this comment.

20 As far as the comparisons with dosimetry  
21 measurements, we just note that the calculations of plant  
22 dosimetry are required and are done routinely at all the  
23 plants. So these really -- there is plenty of information  
24 out there on how to do these calculations of the dosimetry  
25 measurements, and with the NUREG-6115, this includes

1 examples, several examples. It includes the calculation and  
2 it includes how you do the calculation and the results. So  
3 we think that with respect to 6115, the benchmark problems,  
4 there is plenty of information out there on how to do  
5 benchmark calculations.

6 The next comment was that the simulator  
7 experiments do not provide sufficient detail to perform the  
8 benchmarks. This is similar to the previous question. As I  
9 said, we added references, additional references.

10 The next comments is that there are no results  
11 available that use the DG-1053 method and I would say that  
12 the NUREG-6115 report includes benchmarks results that have  
13 been determined used the methods of the Reg. Guide. There  
14 is also several of the benchmark experiments out there that  
15 are references, the H.B. Robinson experiment by Oak Ridge  
16 uses the methods of the Reg. Guide. And as Lambros  
17 mentioned a few minutes ago, several of the licensees, the  
18 Palisades and Beaver Valley calculations have been carried  
19 out using the methods of the guide.

20 So the methods of the guide are -- references of  
21 the application of the methods are fairly -- are available.

22 The next comment was that the benchmark problems  
23 were done with the BUGLE-93 library and the DORT code.  
24 Well, the calculations were done -- those libraries are a  
25 couple of years out of date. They have a new library now,

1 BUGLE-96, and there is a new code called DOORS, which is  
2 actually a new version of DORT. And the comment was, well,  
3 we should do the NUREG problems using these new libraries  
4 and the new code.

5 And we agree that the codes, the nuclear data are  
6 being changed continuously, and we are presently reviewing  
7 this new library and this new code, and if we find that the  
8 differences have a significant effect on the application of  
9 this report and there is a need to revise NUREG-6115, that  
10 will be considered. And so we got in a time warp here, we  
11 can't keep up with the changes. But I really think, I am  
12 fairly confident that the changes are not that significant  
13 in those libraries and the code.

14 The next comment was additional guidance should be  
15 used in qualifying calculations and what constitutes an  
16 acceptable solution. Well, what we say here, we have added  
17 text to the guide that states basically that when you do the  
18 benchmark problem, if the differences between the benchmark  
19 problem calculation and the reference solution are  
20 substantially larger than what would be expected based on  
21 the difference in the methods approximation, the nuclear  
22 data, the calculation would be considered unacceptable.

23 In this case, if we get very, very large  
24 differences, when you do the benchmark problem, if you get  
25 very large differences, what do you do? Well, the

1 calculation should be reviewed and the differences  
2 explained. And if the differences are due to an error in  
3 the calculation, the method should be revised. So that is  
4 how we address that.

5 CHAIRMAN SHACK: What is a very large difference?

6 DR. CAREW: Well, when you see -- who has the  
7 question? Okay. When we get to the benchmark problems, you  
8 will see. That is the next subject and you will see, we can  
9 discuss it at that point.

10 Okay. The next comment was, in addition to the  
11 solutions calculated with DORT and MCNP, there are other  
12 codes out there that we should use, namely, this is -- DORT  
13 is the Oak Ridge code, TWODANT is the Los Alamos code, and  
14 they are both discrete ordinates codes. This is an AEA  
15 Monte Carlo code, MCBEND, and this is -- I believe, I think  
16 that is what it is, yeah, it is AEA. And this is the Los  
17 Alamos Monte Carlo codes.

18 Now, all of these codes have been extensively --  
19 they basically all use, you know, the Monte Carlo methods  
20 use very similar methods and so do the discrete ordinates,  
21 and they have all been well benchmarked and they have been  
22 around for a long time, so the code to code variations will  
23 be small. And as a matter of fact, you will see when we  
24 look at the benchmark problems comparison, they are very  
25 small. Even when we compare these two codes, the

1 differences are, you know, are very, very -- are small.

2           So, we would expect, and I am very confident that  
3 if we use these other codes that the code to code  
4 variability would be much less than the uncertainties we are  
5 concerned about. We are concerned about uncertainties of 10  
6 or 20 percent. The code to code variability would probably  
7 be of the order of a few percent. So that would be of  
8 interest, might be of some interest for code development or  
9 whatever, but looking at what we are looking at here, if  
10 somebody, if a licensee submitted, for example, a code with  
11 TWODANT, I don't think that, you know, it would be a major  
12 concern here. Okay. That was that question.

13           Okay. The next question was a request or a  
14 suggestion that if the purpose of the benchmark problem is  
15 to validate the implementation and the interfaces of the  
16 code, why not just provide the licensee the electronic input  
17 of the input data and the solution and they can just do it  
18 all electronically. But the point here is that the purpose  
19 of the benchmark problem is not to just validate the  
20 implementation of the code or the interfaces, it is also to  
21 validate the methods approximations and your set-up, and all  
22 your mesh and everything else. And if we provided the  
23 licensees both the input and the output, it would defeat  
24 that purpose, it would not be really a valid test of their  
25 methods. So we had to -- we couldn't, we didn't make any

1 changes as a result of that comment. I think that was the  
2 comment, right. Yeah.

3 Okay. All right. Another comment was that the  
4 guide requires that the measurement, the laboratory  
5 measurement methodology be validated every few years, or  
6 periodically, and the comment was that we should quantify  
7 this statement every few years. Rather than saying every  
8 few years we should require that the laboratories validate  
9 their methodologies every two years or whatever.

10 And we have had -- it is amazing, we have had  
11 discussions of this issue for a long time, from day one  
12 basically. In any case, we have talked to other  
13 laboratories, we have talked to people that do the  
14 measurements, and the consensus overwhelmingly has been to  
15 leave the flexibility in there so that -- because there is a  
16 substantial variation from laboratory to laboratory as to  
17 the systems they use, the procedures, whatever, and we  
18 should allow them some flexibility so that they can set  
19 their own, you know, their own reasonable frequency of  
20 validation.

21 And then the last comment we thought was  
22 significant concerned the least squares approach. I don't  
23 know if you are familiar with this, but in this area, there  
24 are ways of -- you do a calculation and you do measurements.  
25 And after you do the measurements, you may want to go back



1 and change your calculations. And there is basically two  
2 methods of doing that. You take your measurements, and you  
3 take your calculations, and you make ratios and you look at  
4 them to get a mean value and you determine that has a bias,  
5 and maybe if you really feel that that bias is really a  
6 solid number and reliable, and may help you, whatever, you  
7 would apply that as a multiplicative factor directly onto  
8 your calculation, and that is a direct deterministic method  
9 of doing that adjustment.

10 But, on the other hand, there are more  
11 sophisticated techniques that form the same ratios,  
12 measurements to calculation, but they take these into a set  
13 of ratios and they look at them statistically, and they  
14 build in different degrees of freedom into the calculations  
15 and measurements, and they take these degrees of freedom and  
16 they adjust them so they minimize the least squares  
17 difference.

18 So, anyway, some licensees use one approach and  
19 other licensees use this least squares adjustment approach.  
20 And some of the guidance in the guide I guess implied that  
21 we were excluding the least squares approach. So the  
22 comment was that the guidance conflicts with the least  
23 squares approach. Well, we have gone back into the guide  
24 and looked for any areas where the conflicts occurred and  
25 eliminated them. And this comment also suggested that we

1 reference the ASTM standard on least squares adjustment,  
2 which we have done. So that is how we have addressed this  
3 comment.

4 DR. TSOULFANIDIS: John.

5 DR. CAREW: Yes.

6 DR. TSOULFANIDIS: Going back to 51, what if you  
7 say, instead of "every few years", "as deemed necessary",  
8 meaning if nothing new has developed in measurements and  
9 nothing has shown that measurements were done incorrectly,  
10 there is no need to do anything. But suppose a new  
11 development comes in, a better detector, a better technique,  
12 if you did the measurement today, you may have to revise it  
13 a month from now.

14 DR. CAREW: Yeah, I guess -- I hear what you are  
15 saying.

16 DR. TSOULFANIDIS: You may not have to do anything  
17 in 10 years, but you may -- Lambros.

18 MR. LOIS: This is Lambros Lois. There is such a  
19 provision in 50.61. It says that any significant difference  
20 in your calculations or measurements, you should report it.

21 DR. TSOULFANIDIS: I thought this refers to  
22 measurements only. Every few years, revise the measurement  
23 procedures or techniques.

24 MR. LOIS: Yes, but what I am saying is that there  
25 is an all inclusive provision in 50.61.

1 DR. TSOUFANIDIS: Okay.

2 CHAIRMAN SHACK: I wanted to suggest that this  
3 seems to me a good place for a break since we have finished  
4 with the NEI comments.

5 DR. SEALE: Yeah.

6 DR. CAREW: Good idea.

7 CHAIRMAN SHACK: Just take a break for 15 minutes.  
8 We will be back at 10:15.

9 [Recess.]

10 CHAIRMAN SHACK: I would like to resume our  
11 discussion.

12 DR. CAREW: Okay. The next comment was that --  
13 this was by Ali Haghighat from Penn State, was that it  
14 wasn't clear that the Regulatory Guide methods, methodology  
15 was applicable to the BWR because of the fact that there is  
16 a substantial axial void distribution up the core axially,  
17 and also because of the fuel isotopics. And we have applied  
18 the methodology to a BWR benchmark problem in NUREG-6115,  
19 which I will discuss in a few minutes. So you will see  
20 that, in fact, we divide the core up into seven axial zones  
21 to accommodate that axial void behavior, and we know that  
22 this is adequate.

23 Let's see, the next comment from Ali was that the  
24 verification of the variance reduction method used in the  
25 fluence calculation is impractical, impossible. Now, as I

1 mentioned before, because of the strong attenuation, when  
2 you do a Monte Carlo calculation, you have to somehow  
3 increase the statistics, pool your statistics, and what you  
4 do, one common technique is to split the neutron, so as the  
5 neutrons come in from region to region, that one neutron  
6 becomes five neutrons, becomes 10 neutrons, becomes 20  
7 neutrons. So when you get to the vessel, instead of having  
8 that one neutron, you may have a hundred neutrons or a  
9 thousand neutrons, and that way, the variability is amongst  
10 the 1,000 neutrons, so the statistical fluctuations are  
11 much, much smaller. Instead of having one stock, you have a  
12 mutual fund which has a thousand stocks and the fluctuations  
13 are much, much less.

14           Anyway, so, that is how you get around the  
15 variance reduction problem. In all these variance reduction  
16 techniques, there is an approximation involved. And, as you  
17 might imagine, you don't get anything for nothing. If you  
18 reduce that variance, there is something you are cheating  
19 somehow and there is an approximation. And you must show  
20 that that approximation is valid, there is no error in that.  
21 And the guide recognizes and says, if you use variance  
22 reduction method, that is fine, but you must verify that you  
23 are not introducing a bias or there is not an error coming  
24 in. So we require it to be validated, and this comment  
25 says, well, it is impractical, impossible to validate it.

1 Well, when we ran the benchmark problems, we used  
2 a variance reduction technique. And what we do is we run  
3 two problems, one problem with the variance reduction and  
4 one problem without, and show that the results -- you know,  
5 it is just one case, you do that once, and show the variance  
6 reduction works. It is not valid -- it is valid, and then  
7 it is verified.

8 So, in response to this comment that it is not  
9 possible or practical, we have used it. We have actually  
10 verified this and carried this process out in the NUREG  
11 problems.

12 Yeah. Go ahead.

13 DR. TSOULFANIDIS: John, should you add to this  
14 the fact that you calculate fluxes using the Monte Carlo  
15 biasing techniques, et cetera, you use these fluxes to  
16 calculate dose rates, and you compare these calculated dose  
17 rates with the measured ones?

18 DR. CAREW: Right.

19 MR. LOIS: And that is another way to see how good  
20 your Monte Carlo results are.

21 DR. CAREW: Right. But I think that when you  
22 compare -- unfortunately, when you compare the measurement,  
23 you have to have a very good measurement. And, typically,  
24 the measurements, if you are going to try to validate your  
25 variance reduction technique, your splitting technique, for

1 example, by comparing that to a measurement, you always have  
2 the problem, you know, the measurement, you introduce the  
3 measurement error and your measurement error may only be  
4 good to 20 percent. So you are really -- and, usually, when  
5 you run the Monte Carlo, you can run it down till you get  
6 statistics of like, you know, a few percent.

7 So, presumably, you would like to have a  
8 comparison that would see an error of 5 percent, and the  
9 measurement errors usually are larger than that and you may  
10 not be able to see -- you may not be able to get a credible  
11 or reliable validation of the variance reduction method  
12 against the measurement. So we would say the cleanest way  
13 to do it is take one calculation, use the variance  
14 reduction, and to take the same calculation with the same  
15 model, the same, you know, everything, everything exactly  
16 the same except you have no variance reduction. And this  
17 way you can see exactly the difference in those two  
18 calculations would be the effect of the variance reduction.  
19 And then it should be that both numbers agree to within the  
20 statistics.

21 DR. TSOULFANIDIS: Correct. But --

22 DR. CAREW: Okay. I missed your point, go ahead.

23 DR. TSOULFANIDIS: Not everybody will use the same  
24 variance technique. So if you did this for one specific  
25 problem, what you propose there is fine. But person B uses

1 different variance techniques and this is not validated.

2 DR. CAREW: Okay. But the guide says the  
3 licensee, the analyst must validate his technique.

4 DR. TSOULFANIDIS: By doing this?

5 DR. CAREW: By doing this. So if vendor X comes  
6 in and he wants to use a variance reduction technique,  
7 whatever it is, it is may be splitting, it may be some other  
8 technique, but whatever it is, that is an approximation and  
9 he must validate it.

10 DR. TSOULFANIDIS: So for one case, they have to  
11 do analog Monte Carlo?

12 DR. CAREW: They must do a full Monte Carlo  
13 without the variance reduction, right. Some case that would  
14 do that. He has to pick out some case, maybe it is only a  
15 1-D radial or a 1-D axial, it may be a simple calculation,  
16 but he has got to show that his, whatever trick he is using  
17 is valid.

18 It is just like using a discrete ordinate method,  
19 if you use a group structure of 47 groups, and you have got  
20 to show that that 47 group approximation is valid. So we  
21 consider the use of a variance reduction method, whatever it  
22 is, that is an approximation and there are certain  
23 assumptions built into that and they must be verified. And  
24 it is really important because these Monte Carlo  
25 calculations and the variance reduction techniques are

1 complicated, they are subtle, you have to be very careful.  
2 And it is hard, you know, in any case, we have this --

3 DR. TSOULFANIDIS: Absolutely. They are called  
4 biasing techniques, but the trick is not to bias your  
5 result.

6 DR. CAREW: Not to bias it, right.

7 DR. SEALE: Thank God you have got the computers  
8 now that allow you to run these full Monte Carlos in a  
9 reasonable amount of time.

10 DR. CAREW: Right.

11 DR. SEALE: I mean the desktop machines do a  
12 remarkable job on some of these.

13 MR. LOIS: This is Lambros Lois again. But what  
14 Tsoulfanidis suggests would be ideal, would the best of all  
15 worlds. Unfortunately, the variation between -- on  
16 dosimetry measurements, between reactor to reactor, are  
17 quite significant, and even for the same capsule, we get  
18 significant variations between dosimeter to dosimeter and it  
19 would next to impossible to make sense out of that. So,  
20 therefore, you cannot use a measurement to, you know, verify  
21 the uncertainty for that.

22 CHAIRMAN SHACK: Just coming back to your comment  
23 one on the BWRs. Again, you know, I have shown an  
24 approximation is valid for one case. You know, how  
25 home-free does that get me?



1 DR. CAREW: Well, I mean if you look and ask  
2 yourself, you know, what is it about a BWR that would make  
3 these methods inapplicable, and the only question really is  
4 the void distribution.

5 CHAIRMAN SHACK: Does that mean every BWR is going  
6 to have to do, you know, five splits and then 10 splits and  
7 see if he gets a big difference?

8 DR. CAREW: No. I mean with the seven, dividing  
9 up the seven regions, the error, the error in the void  
10 fraction is less than the input void fraction. In other  
11 words, you calculate the void to be 30 percent, but, you  
12 know, the core calculation of the void fraction is 30  
13 percent, that is plus or minus a couple of percent. Well,  
14 when you break it up into seven nodes on the periphery, the  
15 error in the void fraction is less than -- is of the order  
16 of the error in the input void fraction.

17 In addition, if you are the on ex-vessel wall, you  
18 are looking at, you know, you would be looking back at the  
19 vessel, but you might be looking at three different zones,  
20 okay, not just one zone. And each one would have their own  
21 error. You might be high here, low here. So it would  
22 integrate out and the error would be much smaller. So we  
23 believe seven is more than adequate for a treatment of the  
24 voids.

25 MR. HOPKINS: Bill Hopkins with Bechtel, but I am

1 going to put on ANS-6 hat as the Chairman of the ANS-6  
2 standard, and give some more historical data. In '85, EPRI  
3 funded SAIC to calculate what is a classic report on  
4 pressure vessel embrittlement with the state of the art  
5 then. And they did both the PWR and the BWR case. And they  
6 focused on this BWR void distribution as the key. But at  
7 the same time they also had the opportunity to go down and  
8 instrument Browns Ferry. That data is proprietary, but it  
9 exists. But it did benchmark the fact that even in '85 the  
10 methodology, which was the DOT at the time, with that -- I  
11 guess that was the Saylor cross sections that they were  
12 using, was sufficient to get you the responses.

13 It is something that is available through EPRI.  
14 But I always refer anybody wanting to try to calculate  
15 things like this for the first time, since 6115 isn't out,  
16 to go take a look at EPRI NP-152.

17 DR. CAREW: Thanks, Bill.

18 MR. LOIS: John, can I add one more comment?  
19 Since we are on the step, John, of this discussion, an  
20 additional difficulty with BWRs is the presence of the pumps  
21 and the risers. Unfortunately, because it is not  
22 cylindrical in nature, so it can be incorporated readily  
23 into two-dimensional calculation, they introduce a  
24 significant perturbation into the calculation and the  
25 prediction what is beyond that.

1           What makes that even more significant is that --  
2   and rather unfortunate, is the GE practice to locate niobium  
3   and iron dosimeters right behind the pumps, with an enormous  
4   amount of iron. Of course, the spectral distortions were  
5   tremendous. And you get some measurements which most of the  
6   time you don't know what they mean anyway. So those are  
7   difficulties which have to be faced for the BWRs.

8           DR. CAREW: Okay. I have one more comment, and  
9   this was the comment from Bechtel Power, Bill Hopkins. And  
10   his comment was that he suggested the attached figure should  
11   be included in the guide to clarify the dependence of the  
12   fluence determination on fluence uncertainty. And we  
13   thought that was a good suggestion and we have incorporated  
14   that figure as Figure 4 in the guide.

15           Okay. Now, I would be willing to discuss any  
16   other comments, any specific comments, if anybody has any  
17   questions about any specific comments at this point.

18           [No response.]

19           DR. CAREW: Okay. All right. Now, I will go on  
20   to the pressure vessel fluence benchmark problem report, and  
21   some comments were raised earlier and, hopefully, this will  
22   address those comments. The NUREG report includes a set of  
23   pressure vessel fluence benchmark problems and solutions.  
24   The purpose of this report was to ensure the accurate  
25   fluence predictions and quantify uncertainty, and to

1 standardize vessel fluence methods, and simply and  
2 streamline the licensing process. That was the purpose.

3 The way the benchmark problems would be applied is  
4 as follows, the methods are presented in great detail in the  
5 Regulatory Guide, and in the benchmark problem report, this  
6 provides the definitions, a complete definition and the  
7 reference solutions for these problems. The licensee would  
8 calculate the benchmark problems and provide the comparisons  
9 to the reference solutions to the NRC. And I would just  
10 like to say at this point, that, in fact, a licensee has  
11 just recently submitted the solutions to these problems to  
12 the NRC for approval as part of their submittal for the  
13 methods and provable.

14 And then, finally, the fluence methods would be  
15 accepted based in part on the agreement with the reference  
16 solutions. Okay. That is how the benchmark problem report  
17 would be applied, intended to be applied.

18 Now, the problem definition for the problem, we  
19 looked at four different types of cores. We looked at three  
20 PWR cores, a standard core and a low leakage fluence  
21 reduction core, and a partial link shield assembly fluence  
22 reduction core. And we have also looked at a BWR core.

23 The problem definition includes a description of  
24 the problem materials, geometry and pin-wise source. For  
25 each pin -- well, for each bundle, we provide the bundle

1 power, the exposure, the burnup of that bundle to get the  
2 plutonium buildup, and we also provide the actual pin-wise  
3 power for the peripheral assemblies.

4 The problem is defined for typical operating  
5 geometry and materials, and the report includes a complete  
6 fluence analysis and execution of all the steps required for  
7 the RT PTS input.

8 I am now going to describe some of the problems.  
9 It is typical core-to-cavity dimensions, materials. A  
10 complete, detailed set of calculational input was provided.  
11 One of the things we were concerned about in defining these  
12 problems, we wanted to make sure that the problem included  
13 every single piece of data that was required, except maybe  
14 the speed of light and a few other things. But everything,  
15 everything was there, and we made a great effort to do that.

16 We have dosimeters on the standard wall capsule,  
17 on the vessel inner wall, and also in the cavity, and we  
18 have accelerated capsules. And we also provide the  
19 dosimeter ENDF-VI cross sections. So the user can use those  
20 cross sections and the cross sections will divide out of the  
21 comparisons.

22 Here is a picture of the actual problem. The red  
23 is the fuel, this is the core. We have got the baffle, the  
24 core barrel, the thermal shield. We have a capsule on the  
25 back of the inner wall of the thermal shield and a capsule

1 on the vessel inner wall. We have a cavity capsule and a  
2 concrete shield. This describes the interface right here  
3 and we have the coordinate system. The coordinate system is  
4 important because when we give the pin-wise power in these  
5 peripheral assemblies, we need to know the orientation of  
6 the coordinate system. That is the PWR problem.

7 We also did a BWR, here is the BWR geometry.  
8 Again, here is the core region. The baffle, the shroud, the  
9 jet pumps and risers are included. The pressure vessel wall  
10 insulation and the concrete shield. As I mentioned before,  
11 we did, in the BWR, we have -- the axial treatment, a  
12 definition of the core is more complicated than the PWR.  
13 There is seven axial zones. And the steam separator and  
14 dryer regions, the core plate. Okay.

15 As I mentioned to you, the problem includes the  
16 complete geometry, the inner inlet thickness, the vessel  
17 clad thickness, all the geometry is included and all the  
18 temperatures and materials. And this problem has the  
19 advantage of you try to go and calculate a measurement, you  
20 know, a benchmark measurement, dosimetry in the capsule, you  
21 have the problem that you don't -- this problem doesn't have  
22 the uncertainty in the source. The source is completely  
23 specified. The vessel diameter, the geometry is completely  
24 specified. The material compositions will be completely  
25 specified. Everything is fixed. So the only thing should

1 be different if two people calculate this problem is the  
2 implementation of the codes, the interfaces, and the  
3 approximations used in modeling the core. A representation  
4 of the jet pumps, how you represent those, all these  
5 different approximations that enter, they can be compared  
6 and validated very easily and cleanly in these comparisons.

7 This is the compositions for each isotope, here is  
8 the very fuel, the very fissionable isotopes 235, 239 and  
9 240. So the whole problem is completely specified. And the  
10 solutions are tabulated based on standard fluence  
11 predictions. The flux is given, the flux above 1 MeV, about  
12 .1 MeV and DPA in the spectrum. We have also included in  
13 the report sensitivity calculations to various numerical  
14 schemes, you know, the various -- we did the calculation, we  
15 also provided a whole table of sensitivities. The selection  
16 of the quadrature S8 versus S16 and all the different  
17 assumptions, the numerical assumptions that we made, we  
18 provided sensitivities in the report. It is done with S8  
19 P3. We have a synthesis, BULGE-93 cross sections, et  
20 cetera.

21 DR. SEALE: John, I have a quick question.

22 DR. CAREW: Yeah, go ahead. Yes.

23 DR. SEALE: The R theta diagram you showed what, a  
24 45 degree sector?

25 DR. CAREW: Segment, right.

1 DR. SEALE: Do you then assumption reflection  
2 around those boundaries?

3 DR. CAREW: The guide states that if the core has  
4 octant symmetry, you can do the calculation in octant  
5 symmetry. And, typically, PWRs will have octant symmetry.  
6 But if the symmetry is broken, you may need to run a quarter  
7 core calculation.

8 DR. SEALE: I see. Okay.

9 DR. CAREW: Also, the layout of the jet pumps for  
10 BWRs is not always --

11 DR. SEALE: Scallop shield.

12 DR. CAREW: It is not always octant symmetric.  
13 So, depending upon the symmetry. Also, we say that if the  
14 peak fluence is in one octant, they could look at that  
15 octant. Or if a particular capsule may be in one octant,  
16 they may want to look at just that octant.

17 DR. SEALE: Yes. Yes.

18 DR. CAREW: But, of course, these are very  
19 expensive and time-consuming calculations, so you don't want  
20 to set up more of a jump than you really need. But you have  
21 to make sure that the system you are looking at has the  
22 proper symmetry, et cetera, to do that.

23 DR. SEALE: Sure.

24 CHAIRMAN SHACK: Just, in the nature, when you say  
25 these time-consuming calculations, what are we talking about



1 on a modern computer?

2 DR. CAREW: Well, the discrete ordinate  
3 calculations are not that time-consuming, they may be five  
4 or 10 minutes, something like that maybe. But the Monte  
5 Carlo are really costly. They really take a lot of time.  
6 And that is the reason why we didn't have those in the guide  
7 initially, we thought that they would be too expensive and  
8 people wouldn't run them. And they might be an experimental  
9 tool, but not a design tool. But apparently there actually  
10 are -- they are creeping into the design tool, the design  
11 scheme, and as computers improve, so that is why we  
12 incorporate it. And those are very, very expensive, I mean  
13 they take a long time, days, weeks.

14 CHAIRMAN SHACK: Oh, okay. I mean we are talking  
15 that kind of time.

16 DR. CAREW: You are talking long, maybe even  
17 months.

18 DR. SEALE: There is one other comment here that I  
19 think is worth noting, and that is that the ENDF/B-VI cross  
20 sections mentioned here are different primarily in the way  
21 in which the details of the iron cross sections in the  
22 MeVish range, which is important here, are handled. And  
23 that work was actually financed by the NRC, as I recall,  
24 back in the late '80s and early '90s, essentially as a  
25 precursor to this evolution. And think when we hear people

1 criticizing fundamental, so-called fundamental tasks and so  
2 forth, money spent on things that sound exotic sometimes,  
3 that it is instructive to recognize that here is some work  
4 which has immediate and serious impact on probably one of  
5 the most important questions facing the industry right now,  
6 namely, the credibility of the whole process of license  
7 extension. And so it is important to recognize that  
8 fundamentals count, too. This is a good example.

9 DR. CAREW: If I may say something, go one step  
10 further, that work actually resulted in identifying a  
11 substantial non-conservative in the fluence dose to the  
12 vessels, so I agree.

13 MR. LOIS: This is Lambros Lois again. Dr. Seale,  
14 thank you very much for recognizing that the need for this.  
15 I am the primary consumer of that information and the result  
16 of that research.

17 Going back to the symmetry that you mentioned, 45  
18 degree, unfortunately, when some of the plants that tried to  
19 implement severe reduction in the leakage, and they tried to  
20 protect non-octal symmetry axial welds, they have to destroy  
21 the octal symmetry. In fact, they have one reactor that  
22 destroyed even the quarter symmetry and they are graphically  
23 about a half symmetry.

24 In that case, they can still go back and work on a  
25 45 degree angle -- I mean segment, provided that the one

1 that they work on is the one that contributes the most to  
2 the inside side of the pressure vessel.

3 DR. TSOULFANIDIS: I was going to say there is no  
4 true symmetry anyway. The question is how much asymmetry  
5 you are willing to accept.

6 MR. LOIS: Yes. Yes. Yes.

7 DR. SEALE: Right. It is a computational  
8 artifact.

9 MR. LOIS: Right. Right.

10 DR. TSOULFANIDIS: If you take the conservative  
11 quarter, yes.

12 MR. LOIS: Yes.

13 CHAIRMAN SHACK: Just coming back to, you know,  
14 your R theta meshes, I didn't notice any sensitivity studies  
15 where you varied the mesh geometries. I mean, you know, you  
16 picked a mesh and you did the calculation. Was that  
17 presumably based on previous studies?

18 DR. CAREW: Yeah, we have done, and you will see,  
19 the same way we do the comparisons with the MCNP, exactly  
20 how much that contributes. But we have done -- I have  
21 worked for Lambros over the years, and dating back -- well,  
22 over the years, these mesh were not just created here, we  
23 had a lot of experience, had done sensitivity calculations  
24 of what mesh was adequate. And, as a matter of fact, the  
25 guide specifies what an adequate mesh is, and that is based

1 on previous -- the calculations that we have done that  
2 identifies the sensitivity to do that. Actually, it is --  
3 what you have there, you have a Cartesian core and you have  
4 a polar coordinate system, an R theta coordinate system, and  
5 you have to map that peripheral geometry into little arcs.  
6 And the arc has got to be pretty small. Kind of like, if  
7 the boundary is like this, each arc has to cross it like  
8 this, like this, so you are going like this.

9 And that mesh, it turns out if you take enough  
10 mesh, and we do, and the industry does basically now, that  
11 that is a pretty small effect.

12 CHAIRMAN SHACK: What saves his bacon, too, is the  
13 fact that there is a lot of attenuation in the core. And so  
14 if you are sitting here looking at the core, it is the piece  
15 right in here that is closest to you and thinnest that  
16 dominates the dose out here. And this stuff gets kind of  
17 hidden in the self-attenuation in the core that is in front  
18 of it.

19 DR. CAREW: And, also, like if you make an  
20 approximation for this segment here, this segment will be  
21 low and this will be high, but these are very small  
22 segments, so at the inner wall, you are not just looking at  
23 that one small segment, you are looking at a whole  
24 integration of a summation of all those pieces.

25 So it gets to be, you know, it is about on the

1 order of a percent or two. But, of course, mesh will be 2  
2 percent, a fine mesh would be 1 percent, something of that  
3 order.

4 So, okay, let's see. The next slide is a slide  
5 showing the typical results. Here we have the fluence, the  
6 significant figures. This is a function of azimuth angle as  
7 you go around the vessel in a wall, and this is at the inner  
8 wall, quarter T, half T, three-quarter T and full thickness,  
9 and these allow a detailed comparison of the results.

10 Okay. Now, the next step was to discuss the Monte  
11 Carlo calculations, and this was, as we mentioned, this was  
12 a round two comment, which we have added as a result of the  
13 round two comment. And so what we have done is we have gone  
14 back, and after having done discrete ordinate calculations,  
15 we have gone back to those problems and redone them with  
16 Monte Carlo. As we know, Monte Carlo is an entirely  
17 different methodology. The geometry is represented by  
18 surfaces, each surface as far as the problem is explicitly  
19 represented in the problem.

20 We looked at a standard core, a partial link  
21 shield assembly core and BWR core, I thought these were a  
22 fairly complete set. The Monte Carlo includes exact 3D  
23 geometry. We have a pin-wise -- the source is defined for  
24 each rod, it goes in explicitly, individually. And we have  
25 the same basic cross sections as the DORT calculation.

1           And I might add at this point we could have gone  
2 to BUGLE-96. BUGLE-96 had been on the street at this time,  
3 but we thought consistency is more important than the latest  
4 set of cross sections. We want to have the MCNP and the  
5 DORT, everything exactly the same and compare apples and  
6 apples.

7           So, let's see, and I might just say that we have  
8 used a region-wise importance variance reduction, or  
9 splitting, so the neutron is split. It is kind of  
10 interesting, each neutron that emerges from the core, by the  
11 time it hits the vessel, is a thousand neutrons, basically,  
12 to accommodate the factor a thousand attenuation.

13           We edited the flux above 1 MeV. Of course, with  
14 the Monte Carlo it cost. The lower the neutrons go, the  
15 lower you go, the much more expensive, and these  
16 calculations were very, you know, they are very, very  
17 time-consuming even on today's computers, especially if you  
18 make a mistake and have to redo it.

19           CHAIRMAN SHACK: This neutron splitting, is this  
20 what I think of as stratified sampling, that I am really  
21 taking samples from the neutron spectra that are the ones  
22 that get to the wall?

23           DR. CAREW: No, it is not the same.

24           CHAIRMAN SHACK: It is not the same thing.

25           DR. CAREW: The same is that you have a neutron

1 that comes into one region and there is a boundary here, and  
2 as it enters that region, you say I am going to split that  
3 to four neutrons, say, for example. And you split it, it is  
4 now four neutrons. But what you do, and it is the same  
5 direction and orientation, whatever energy, but you now, to  
6 make it a fair game, you have got to reduce the weight in  
7 between those neutrons. If the weight of that initial  
8 neutron would start out to be 1, say, for example, now it is  
9 .73, and it is now four neutrons, you have got a sample, so  
10 the weights of these four neutrons carries the same amount  
11 of weight as the original one.

12 But the advantage is that when that neutron gets  
13 to the vessel inner wall, it is a thousand neutrons or, you  
14 know, 920 or whatever it is, and, as a result, the  
15 variability in your results, if one of those neutrons  
16 underwent a scattering in some region, it would only have a  
17 small -- or if one of those neutrons went straight through  
18 and hit the vessel directly, the vessel, the edit wouldn't  
19 jump up because it carries a small weight. Whereas, if it  
20 was one neutron and it went straight through, the tally on  
21 that edit would go way up, and the variance, when you took  
22 the mean value of that location, the mean value would be a  
23 certain number of neutrons, plus or minus 500 percent, or  
24 100 percent, whatever. So that is how it works, it is not  
25 the same as stratified sampling.

1           Okay. So we have done these calculations. And as  
2 I mentioned, as we cut the problem off, you know, at 1 MeV  
3 because they are very expensive, and that was sufficient for  
4 the comparison. And interesting enough, we find that the  
5 agreement, after we ran enough histories, that the agreement  
6 was within 5 percent, roughly 5 percent. We were very happy  
7 with this result in view of the differences in all the  
8 methodologies. This 5 percent is due to the MCNP statistics  
9 which were about 4-1/2 percent, the DORT geometry  
10 representing the Cartesian geometry with this planar or  
11 radial coordinate system, polar coordinate system.

12           The DORT numerics, the fact that we have only a  
13 certain number, 50 angles, 48 angles to cover the sphere.  
14 And the fact that we are doing a synthesis. We do a radial  
15 calculation and an axial calculation. There is always a  
16 concern, you know, we can't do 3D, we are doing a synthesis  
17 calculation, how do you know that the radial and axial is  
18 separable? There is that issue. And this put that to bed.

19           So, anyway, now let me show you the results.

20           DR. TSOULFANIDIS: John.

21           DR. CAREW: Yes.

22           DR. TSOULFANIDIS: So the statistical  
23 uncertainties of the MCNP were less than 4.5?

24           DR. CAREW: Yeah, I think there were about 4 -- I  
25 think the statistics on the MCNP were maybe 4 percent,



1 something of that order.

2 DR. TSOULFANIDIS: 4 percent. So the 5 percent is  
3 the difference just between the numbers obtained by MCNP and  
4 they don't --

5 DR. CAREW: Right. And I have figures, you will  
6 see.

7 DR. TSOULFANIDIS: Okay.

8 DR. CAREW: So it will be 5 percent, it is very  
9 good.

10 All right. The first case I have a comparison for  
11 the PWR, pressurized water reactor, and as a function of  
12 azimuth. As a function the angle, the flux above 1 MeV,  
13 MCNP and DORT, and you can see they track very well, they  
14 are close.

15 And the next calculation is a partial link shield  
16 assembly core, and I will just show you this core is a  
17 really tough test. And the core, the red is the fuel, but  
18 at the bottom 3-1/2 feet of the core, there is a weld  
19 simulated to be right over here, and the contribution to  
20 this weld comes from this 3-1/2 feet of fuel. And they cut  
21 out -- we have stainless steel rods in here. So we did this  
22 calculation both -- and this is a severe test of a synthesis  
23 also, trying to do a calculation like this.

24 So, in any case, here are the results. Let me  
25 find that. This is the MCNP and the DORT calculation, and,

1 again, they agree very well.

2 DR. SEALE: That sort of confirms it is the outer  
3 skin closest that dominates the dose at a particular point.

4 DR. CAREW: Right. Yeah, we have done special  
5 cases where we have loaded in just the bottom outside row  
6 and we find that 85 percent of the signal is coming from --

7 CHAIRMAN SHACK: Now, would I find somewhat less  
8 agreement if I moved up axially till I, you know, say I hit  
9 that discontinuity? This is at the weld, is where you are  
10 really interested?

11 DR. CAREW: Right. I think probably -- I don't  
12 know. I don't know. Up here, you probably had very good  
13 agreement and it would degenerate somewhat as you get down  
14 here, I guess. But let's see. I don't know.

15 Actually, we do two calculations, we do a planar  
16 calculation and a planar calculation here. So, we are doing  
17 two calculations. I don't know, I really can't speculate if  
18 it would get better. We haven't done that calculation.

19 Okay. That is the PWR, and now this is the BWR.  
20 This is the -- yeah, okay. This is the result at the flux  
21 above 1 MeV at the downcomer and, actually, if you go back,  
22 if you remember, this peak here, which is a substantial  
23 peak, and this peak is due to the fact that the core -- this  
24 is the closest distance between the core and the vessel, and  
25 that is why there is a peak here. But, again, you can see

1 the results were really -- I thought these results were  
2 excellent.

3 DR. SEALE: Where were the jet pumps in there?

4 DR. CAREW: Yeah, good question. The jet pumps  
5 are right over here, right here, and then there are some jet  
6 pumps over here. Let me think. But there is also, there is  
7 a location of close approach between the core and the vessel  
8 here. So this peak and this peak, and this peak here are  
9 due to the proximity to the core, distance to the core. I  
10 looked at that because I was wondering if I could see the  
11 jet pumps on this.

12 CHAIRMAN SHACK: Yeah, I mean you see less wiggle  
13 than you might expect from the geometry, I mean because  
14 there is an awful lot of jet pumps and risers, and yet you  
15 only see sort of, you know, two dips.

16 DR. CAREW: Right. Yeah, I didn't see -- I  
17 couldn't see the jet pumps on this, I really couldn't. But  
18 I know the jet pumps are worth about 13 percent, I know from  
19 previous calculations. So it is in here, but you don't see  
20 any abrupt, and that is probably because these are fast  
21 neutrons and I don't really see, you know, see the detail.

22 Actually, attenuation properties in steel and  
23 water are not that much different. If you go back to that  
24 figure on the beginning of the presentation, you will see  
25 that the fluence drops off rapidly in the water and it drops

1 off fairly rapid in the steel, too, except at the  
2 interfaces, the spectral change that you get to see this  
3 wiggle.

4 DR. TSOULFANIDIS: What I find interesting is the  
5 ratio of the maximum to the minimum in the BWR is a factor  
6 of 5 almost, and in PWR is a factor of 2.

7 DR. CAREW: Right. And that is all dictated by  
8 the core peripheral geometry. We looked at a lot of these  
9 cores and as part of Shah Malik's work, we have been looking  
10 at a whole series of reactors and there we can see the  
11 effect of the core geometry. And it is interesting the  
12 dominant effect is the core geometry. You get some plants,  
13 if I recall, Ocone and Calvert Cliffs -- I think Ocone and  
14 Calvert Cliffs didn't have that much azimuthal variation,  
15 where Robinson had some severe, and it is all dictated by  
16 the distance between the core and the vessel inner wall,  
17 that determines the shape.

18 So we felt that this agreement is very good, and  
19 we feel that if somebody else goes and tries to calculate  
20 these problems, and they are going to be using the exact  
21 same problem, geometry, materials, source, exactly the same,  
22 where other comparisons, there is all kinds of variability.  
23 As you pointed out earlier, than when you construct a  
24 source, you have to go over cycles and go through all this  
25 calculation. That is all factored out of these comparisons.

1 So the only things that should affect these comparisons are  
2 two things, basically, the numerics, the numerical  
3 procedures in DORT, so long as you use DORT, for example, or  
4 MCNP. And those, the effect of the numerical procedures,  
5 you can see should be small. You have a synthesis here, and  
6 the selection of the mesh and everything else. The effect  
7 of the numerical procedure should be small, and if you use  
8 -- these are ENDF-VI cross sections, if you use ENDF-VI  
9 cross sections, even if is a BUGLE-96, I would anticipate  
10 even there, there is not going to be that much difference.

11 On the other hand, if you use BUGLE -- if you use  
12 ENDF-V or earlier cross sections, you would see a large  
13 variation. So if someone did a calculation of this  
14 benchmark problem with an earlier version of the cross  
15 sections, they would get a large difference and they would  
16 become aware that that difference is due to the cross  
17 sections.

18 DR. TSOULFANIDIS: Just a comment. In MCNP  
19 calculations, you can assign error bars.

20 DR. SEALE: Yes.

21 DR. TSOULFANIDIS: Without difficulty. It is much  
22 more difficult to assign error bars to the numerical  
23 deterministic calculations, but we know they are there.

24 DR. SEALE: You know, this is really interesting,  
25 it is almost like two guys getting lost in the woods 30

1 years ago, and one guy goes down a path where he does  
2 continuous slowing down, but he is limited on sample sizes  
3 he can use because of the number of neutrons he can use in  
4 the Monte Carlo. Well, the other guy does the discrete  
5 ordinate transport theory, but he has to use groups, and he  
6 is also limited because he doesn't -- he can't, in his  
7 discrete ordinates, represent the geometry with the kind of  
8 absolute faith that you can put into a Monte Carlo.

9 And suddenly these guys come out of the woods on  
10 the other end, and they got to the same place. And what it  
11 really indicates is a remarkable amount of very good  
12 judgment in which those compromises that were inherent to  
13 the two sets of methods were made in the evolution of those  
14 methods, so that, indeed, they turned out to be the right  
15 kinds of compromises when you got enough computing power to  
16 really hit the problem hard enough to get an answer.

17 There are not too many calculations where you have  
18 the effort put into them to demonstrate this kind of  
19 agreement where you have one or the other. So this has a  
20 lot more value than just in these particular calculations.

21 DR. CAREW: I agree with you, and I think it  
22 really confirms the two people ended up in the same place.  
23 I don't know who is bleeding more, but -- maybe it is the  
24 discrete ordinates guy. But there is a question who is  
25 smarter now.

1 DR. SEALE: Both of them are smart.

2 DR. CAREW: Yes. Okay. There is one more  
3 transparency. And I guess this is really -- I have to  
4 agree, really, it is kind of amazing that we could do this  
5 calculation. And this calculation, in a BWR, you probably  
6 recall that you have a BWR zirc alloy fuel channel with fuel  
7 rods inside and you a void fraction that varies from like 0  
8 to 60 to 70 percent at the top of the core. And then you  
9 have, around that channel, you have a solid water region, a  
10 bypass region. And the question would be, do the neutrons  
11 care whether you take that -- when you do the calculation,  
12 do you mix the whole thing together and make it one  
13 composition, homogenize it, or does it care, do we have to  
14 go and represent those two regions separately, explicitly,  
15 as two different regions? Because you are pushing,  
16 basically, what you are doing is you are pushing water back  
17 and forward. The neutrons in the center of that assembly,  
18 some of those neutrons, if you push the water to the front,  
19 in the back into the bypass region, they are going to be  
20 seeing less water or more water, and you are wondering the  
21 importance of the neutrons and does it divide out or is it  
22 important.

23 So what we did is we did two calculations. We did  
24 one calculation, which was our first calculation, where we  
25 homogenized everything, and the second calculation we

1 divided up and put an explicit water bypass region and the  
2 void region inside. And we did the calculations, in fact,  
3 our first calculation wasn't in such good agreement, we  
4 found a problem in the Monte Carlo. But, anyway, we looked  
5 closer and the calculations actually, I looked at these and  
6 I was kind of hoping I just could see the effect, but I  
7 can't even see the effect, I really can't. With all  
8 honesty, I really can't. Because I understand physically  
9 what should happen, but I can't see it. But this confirms  
10 that approximation, that you could do this in a homogenized  
11 way.

12 But, anyway, that is the end of my presentation.  
13 Are there any questions? I guess I will let Bill do the  
14 next presentation. I will just leave my stuff here.

15 MR. JONES: As I said, John has been involved in  
16 this effort all the time that it has been going on, and I  
17 think people are already getting a benefit from what has  
18 been done. There is already benefit, people are already  
19 using the NUREG and, as Lambros said, people are using the  
20 Draft Guide, so there is already benefit to that.

21 And I think the level of detail that John has gone  
22 into and that this effort has gone into, I think you have  
23 seen an indication of that. On my summary, which is the  
24 last sheet in your small package, John has talked about  
25 this, the level of detail in the guide, and he has just



1 talked about the benchmark and the benefits that has and  
2 what it contributes.

3 When we talked about the history, we talked about  
4 it has been around since '93. We have had several public  
5 meetings, several rounds of comments. We have tried to  
6 really -- we have really been interested, everybody involved  
7 in this has been interested in making it better, and we have  
8 really tried to incorporate comments which we thought really  
9 helped the guide and improved it.

10 At this point the staff believes the guide is  
11 ready. The plan is to have the ACRS full committee on  
12 December 7th and we would like to publish the guide in early  
13 calendar 2001. We plant to publish the NUREG at the same  
14 time. That is really all I wanted to say in summary.

15 If there are any general questions or questions  
16 that we can answer? And, again, I want to thank you for  
17 your time.

18 CHAIRMAN SHACK: How fast do you think this is  
19 going to make a change? You know, if the guy is calculating  
20 away, is he going to suddenly switch? When is he going to  
21 get the heat to lean on him here?

22 MR. LOIS: This is Lambros Lois again. No, we  
23 don't expect any step function to arise because of the  
24 publication of the guide. As we pointed out earlier, all  
25 the licensees are aware of our requirements and they do

1 account for them. As an example, we recently received a  
2 methodology and it practically has all of the -- it shows  
3 cognizance or awareness of all of the contents of the guide.  
4 So all we need to do, actually, what we are going to do now  
5 is to make it official, so to speak.

6 CHAIRMAN SHACK: We have sort of focused on what  
7 an impact might be on PTS. How about other kinds of  
8 embrittlement, would it have a bigger influence?

9 MR. LOIS: Absolutely. We had problems where we  
10 couldn't haven't gotten in the past help from the guide.  
11 The shroud problem, you are aware of that. Internals, core  
12 internals, pressure temperature curves, which are quite  
13 important, and so forth. So the guide will help quite a bit  
14 of application in a variety of areas.

15 CHAIRMAN SHACK: Thank you very much, Mr. Jones.  
16 Any further questions?

17 DR. TSOULFANIDIS: We all know it would be nice to  
18 have in-vessel, ex-vessel measurements to compare the  
19 calculations with, because then you can bracket the result.  
20 And not all plants have ex-vessel measurements. Not all  
21 plants have ex-vessel measurements.

22 MR. LOIS: That is correct. However, in the  
23 context of Appendix H, we did give some guidance in the past  
24 that ex-vessel measurements would be acceptable as a  
25 substitute to satisfy the requirements for Appendix H. And

1 those reactors that they really have an interest in pressure  
2 vessel, or have a problem, I should say, or close, they all  
3 have both, inside and outside measurements, because of their  
4 effort that they try to define the problem they had more  
5 closely, so the readily available thing to do is to go and  
6 get a copy of the measurements, and they have done that.

7 CHAIRMAN SHACK: I think we have a request from  
8 Mr. Warsham of Framatome to make some comments.

9 MR. WARSHAM: I am Tucker Warsham, I am  
10 representing Framatome Technologies, as well as the BWR  
11 Owners.

12 This guide really started to impact us in 1992,  
13 even though it officially wasn't out at that time. We  
14 brought the staff a review from a \$2 million program on  
15 cavity dosimetry and we just completed it. And the staff  
16 informed us that the program was not sufficient without a  
17 reactor vessel calculational approach and a comparable  
18 calculational uncertainty methodology.

19 And, so, as we know, in 1993, February, there was  
20 the industry meeting, and then in September, the first Draft  
21 Regulatory Guide 1025. As far as we are concerned, we  
22 looked at what the fundamentals of the guide were. And the  
23 basic premise is that the current technology that the  
24 industry was using, which really included what we would call  
25 this unfolding or this adjustment technique to assess a

1 measured fluence at dosimetry locations, and the fact that  
2 we then would proceed to extrapolate to the vessel the basic  
3 premise of the Draft Reg. Guide. Of course, this was not a  
4 consistent technology and particularly not consistent with  
5 respect to the way the PTS uncertainty analysis had been  
6 done at Oak Ridge, which was the fundamentals for the safety  
7 analysis of each type of B&W combustion and Westinghouse  
8 core.

9           So, in order to be consistent with the  
10 embrittlement, and particularly the PTS safety, again, what  
11 fundamentally the guide was saying, that if you were  
12 analyzing the vessel, that you should have a calculational  
13 uncertainty and something that could be used to define  
14 accuracy and precision of what the fluences would be at the  
15 vessel.

16           Okay. For several years, Framatome worked on the  
17 fundamentals of what the PTS safety analysis had actually  
18 been, the probabilistic work. We looked at the correlations  
19 that are the heart of Regulatory Guide 1.99, Rev. 2, and our  
20 objection was, of course, to prove that the staff was  
21 erroneous in their assessment that previous technology was  
22 not adequate.

23           Unfortunately, after spending a couple of years  
24 doing this assessment, we found that the staff was actually  
25 correct in their assessment. The old fluence technology was

1 not consistent with the way PTS probabilistic analysis was  
2 doing, the uncertainties could not be shown to be  
3 consistent, and, therefore, additional work would be  
4 required.

5 Okay. The one thing that we found was the staff  
6 estimates in the Draft Reg. Guide what the cost would be to  
7 the industry. We found that this estimate was actually very  
8 much too low. Even John may have estimated, helped estimate  
9 that, as you can hear, if you are running a Monte Carlo code  
10 for a week or a month, and you are actually paying for a  
11 computer to do that, it is quite a bit more costly than what  
12 was originally put out in the guide.

13 What we would like to conclude by saying is, in  
14 consideration of these costs, what has the industry gained?  
15 And in truth, right now, if you say, what tangible benefits  
16 have we gained, we haven't gained any tangible benefits. We  
17 have gained benefits in terms of the plants inherently being  
18 more safe, but there is nothing we can report to and say,  
19 yes, we can extend the life of a plant one year or two  
20 years, or we can do something.

21 What we would like to suggest to the staff and to  
22 the ACRS, that there are now tangible benefits that should  
23 be considered. The first is we have been hammering on the  
24 uncertainties, as John showed. It is amazing, two totally  
25 different analyses, although done by his hand, so, I don't

1 know, maybe there is some question, but two totally  
2 different analyses turned out to be right on top of each  
3 other, meaning that there is quite a bit of reduction in  
4 certainty from fundamental physics.

5 Okay. If there is such a reduction, one question  
6 that Lambros always has is, how are the material people  
7 interfacing with him, which is one of the issues of the  
8 whole draft guide to begin with. But if we have become more  
9 accurate, the inherent uncertainty in the PTS value in terms  
10 of delta temperature and in the pressure temperature curves  
11 for reactors, that uncertainty should be now considered to  
12 be reduced. And I am not saying that we know how, but I am  
13 suggesting that it is time for the fluence part of the  
14 Regulatory Commission and the materials part to get together  
15 and think about what can the industry gain and can we gain  
16 some margin reduction in the materials side because the  
17 fluence is now much more accurate?

18 And we also would like the ACRS and the staff to  
19 consider that now that we are predominantly doing  
20 calculations, 10 CFR 50, Appendix H, references an ASTM  
21 standard, I think it is 185, which requires considerable  
22 dosimetry ever time you are evaluating a reactor.

23 Now, if you conform to the guide, do you continue  
24 to need this much dosimetry, or is it now possible perhaps  
25 to reduce the total number of dosimeters down somewhat,

1 maybe cut them in half?

2 There are two things that we would like to  
3 consider. So, basically, we have finished. If there are  
4 any questions you all have from those comments?

5 No, you know, Dr. Lois, I don't want any questions  
6 from you.

7 [Laughter.]

8 CHAIRMAN SHACK: There is a certain amount of  
9 discussion in the NEI comments, you know, that the Draft  
10 Guide still doesn't provide enough guidance, that it is  
11 going to be difficult to use. Have you looked at it and  
12 tried to use it? Do you have any feeling for whether you  
13 know what kind of rock you are supposed to bring?

14 MR. WARSHAM: From Framatome's perspective, we  
15 finished, we submitted a topical, we have argued with the  
16 staff, and the staff has accepted. So we feel very  
17 comfortable with the guide because we have gone through all  
18 the steps.

19 Before we went through all the steps, we had the  
20 same question as many others had associated with NEI, is  
21 there too much flexibility for the staff to say wrong rock  
22 after hundreds of thousands or millions of dollars had been  
23 spent? Go ahead.

24 DR. TSOULFANIDIS: When you say, should we reduce  
25 the number of dosimeters, what exactly do you mean? If we

1 used 10 thresholds before, they use five now?

2 MR. WARSHAM: That is exactly what I am saying.  
3 Particularly in these two year cycles, what value is a  
4 nickel dosimeter that has a half-life of 87 days? Could we  
5 drop back, stick with some coppers and some uraniums or  
6 neptuniums, cut out some of the iron and nickel? Exactly.  
7 Rather than having four or five different types and three or  
8 four of each of those types, could we shut it down to a  
9 couple of types?

10 And before when we were highly relying on the  
11 measurements and using the measurements for this benchmark,  
12 I think the answer would have been no, but today, if you  
13 have been approved by the guide, if you are fundamentally  
14 now working on analyzing what the calculational technology,  
15 then can't you just use the measurements to continue to  
16 check that each time you do it, that you are okay, but you  
17 don't need quite so many measurements?

18 MR. LOIS: Can I answer that? I am not really --  
19 the problem, I would rather define the problem than answer  
20 it. The question is legal as well as it is practical. In  
21 the practical sense, you are right, we now have sufficient  
22 information, have sufficiently developed the technology that  
23 we can do the same thing with fewer dosimeters.

24 However, the provisions of Appendix H have to be  
25 satisfied, a dosimeter has to be there. Now, that is a



1 legal problem. On the other hand, the slowness with which  
2 the agency moves in changing the provisions of Appendix H,  
3 and Appendix G, for that matter, may have some wisdom in it,  
4 and that is, well, what if things.

5 A long time ago we thought the cross sections, we  
6 knew everything about it within 1 or 2 percent.  
7 Unfortunately, iron, as you know well, changed, and there  
8 are still some far flung questions out there remaining, kind  
9 of wandering around, such as their rate effect, some other  
10 things which we do not know the response to. And although  
11 for a time being it seems as if we are doing a little bit  
12 more to be certain what is going to happen in the future,  
13 particularly with life extension, we would rather do a  
14 little bit more rather than a little bit less, just in the  
15 case in the future something else shows up.

16 So, I agree with you that right now it seems as if  
17 with the improvement in technologies, the need is for less  
18 dosimetry. If we keep it there, keep it up, we may be  
19 better off in the future.

20 MR. WARSHAM: We would be happy to compromise and  
21 have the material people just take a couple of degrees off  
22 the delta T and we will kick the dosimetry in the core.

23 MR. LOIS: I don't speak for them, but, however,  
24 the methodologies that are right now in the works may  
25 actually effectively do that, what you are asking, namely,

1 the introduction of probabilistic methods into the  
2 evaluation of the margin.

3 CHAIRMAN SHACK: Any other comments?

4 [No response.]

5 CHAIRMAN SHACK: I think we can bring the meeting  
6 to a close then. Are there any comments from the other  
7 committee members?

8 DR. KRESS: Are we going to have a letter on this?

9 CHAIRMAN SHACK: Yeah, we are going to have a  
10 letter on this.

11 DR. KRESS: Have you decided on what presentation  
12 you are going to have at the full meeting?

13 CHAIRMAN SHACK: Yes.

14 DR. TSOULFANIDIS: There was a comment in the  
15 beginning of the meeting about 1.99 and an approximate  
16 attenuation factor that is being used now. I assume if this  
17 is approved, then there is no need to use the approximate  
18 factor?

19 MR. JONES: I have a slide. This is an  
20 indication, you can see the red curve in the current  
21 attenuation factor in 1.99, Rev. 2. And this is part --  
22 John mentioned that we have looked at several vessels as  
23 part of the probabilistic PTS work. Okay. So this is a  
24 comparison with a DORT calculation and the attenuation  
25 factor for a vessel. And they are very close for the first

1 couple of inches, and the attenuation is conservative  
2 relative to the calculation. Is that the answer?

3 DR. TSOULFANIDIS: So you will keep using the  
4 conservative approach?

5 MR. JONES: Well, Shah is the PM for the  
6 probabilistic fraction mechanics work and he can address  
7 that issue.

8 DR. MALIK: This Shah Malik again. This  
9 probabilistic has to be done for the whole reactor vessel  
10 and we are using this approximate exponential decay at the  
11 moment. That is being further looked at in Reg. Guide 1.99,  
12 Rev. 3 revision that will be coming up soon also, how  
13 appropriate that term is. But in all likelihood, if it does  
14 not change, that is what we will be using, because those are  
15 like millions of calculations, it has to be on the fly in  
16 the computer to do those, calculating the probability of  
17 failure. And unless somebody builds up such a detailed  
18 model through the thickness of the vessel to go to the  
19 individual points, which the DORT calculation is showing up,  
20 that will make much more complication at the other end.

21 But the licensee does have the option, in their  
22 likelihood, they will save their plan and they can get a  
23 little bit of instructing, they could use that actual  
24 calculation. It is not going to stop them.

25 DR. SEALE: About 3-1/2 or 4 at nine inches is the

1 difference between the two.

2 DR. TSOULFANIDIS: A factor of 4.

3 DR. SEALE: Yeah, 3-1/2 or 4.

4 DR. KRESS: Can't you just change your exponential  
5 function so it fits it better?

6 DR. MALIK: It will be then vessel-specific.

7 DR. KRESS: Oh, it is vessel-specific, okay.

8 DR. MALIK: It will then become vessel-specific.

9 DR. KRESS: Okay. You would have to run a lot of  
10 them.

11 CHAIRMAN SHACK: But how many vessels have you  
12 looked at? John says he is looking at a bunch.

13 DR. MALIK: He is looking at four of them right  
14 now.

15 CHAIRMAN SHACK: Four. Okay. That is a small  
16 sample.

17 DR. SEALE: Yeah.

18 CHAIRMAN SHACK: Do we see a consistent picture  
19 like that, though?

20 MR. JONES: I was just going to see a relatively  
21 consistent picture, yes.

22 DR. KRESS: So you could change it then.

23 MR. JONES: We are in that area of probabilistic  
24 fraction mechanics and that work is being done. We are  
25 exploring options, I guess.

1 DR. CHOKSHI: It is going, I think, you know, both  
2 the probabilistic PTS and Reg. Guide 1.99, we need to look  
3 at the whole thing.

4 CHAIRMAN SHACK: As I mentioned, I mean obviously  
5 you do know more about the uncertainty than you did when you  
6 wrote 1.99, Rev. 2. I mean it just has to be factored in.

7 DR. CHOKSHI: Because some of the other comments  
8 from Framatome, you know, we need to look at the whole thing  
9 and see what are the implications.

10 CHAIRMAN SHACK: I guess maybe the first thing is,  
11 what do we want presented at the full committee? How much  
12 time do we have?

13 MR. DUDLEY: We have an hour-and-a-half.

14 DR. SEALE: Working backwards, I would think it  
15 would be worthwhile to see the comparison between the MCNP  
16 and transport calculations for those four cases. I would  
17 imagine that you could probably sample particularly the EPRI  
18 or the NEI comments.

19 DR. KRESS: I would eliminate most of those  
20 because --

21 DR. SEALE: Yeah, but just to indicate the nature  
22 of the more relevant ones.

23 DR. KRESS: I would just show that pie chart and  
24 indicate maybe the general nature.

25 DR. SEALE: Yes. Yes. Then I think you would

1 probably go through the front part of it pretty quickly.

2 CHAIRMAN SHACK: Okay. That maybe seems to me a  
3 reasonable thing to do, to basically just, you know, very  
4 abbreviate the discussion of the comments, but to keep the  
5 rest.

6 DR. SEALE: The pie chart is a lot of the thrust  
7 really.

8 MR. DUDLEY: How much detail do you need on a  
9 NUREG?

10 CHAIRMAN SHACK: Well, Bob was saying he sort of  
11 liked that detail.

12 DR. SEALE: Well, I think it is the phase of  
13 maturity that I think is important to understand when you  
14 are making these kinds of questions. And I think the  
15 comments from Framatome suggest that at some point down the  
16 road, it may be appropriate to examine some of these issues.

17 DR. KRESS: It seems like a general principle, if  
18 you reduce the uncertainties, you are liable to get some  
19 benefit.

20 DR. SEALE: Yeah. And it is worthwhile for the  
21 committee to know that, you know, the rolling tide of  
22 understanding has gotten to this point, and so maybe it is  
23 going to be time to ask some of these questions again.

24 DR. TSOULFANIDIS: That is not part of this NUREG.

25 DR. SEALE: No, I am not saying that.

1 DR. KRESS: That is something else.

2 DR. SEALE: But it brings the committee up to date  
3 on the status of that calculation.

4 MR. JONES: So what I am hearing is much of what  
5 John presented, you would like to hear in abbreviated form,  
6 and you would like to see the pie chart. Do you want any  
7 comments at all presented by John, or how do you want to  
8 handle that, any of the industry -- any of the public  
9 comments?

10 DR. KRESS: I think the full committee can read  
11 most of those.

12 MR. JONES: Okay.

13 CHAIRMAN SHACK: You have got that nice table.

14 DR. KRESS: You have got a nice table and it is  
15 really easy to follow.

16 MR. JONES: Okay.

17 CHAIRMAN SHACK: One by one, and I think that is  
18 -- you know, the one substantive comment is the one on the  
19 BWR and, you know, rather than the sort of ex cathedra  
20 statement that it works, you know, you might point that out  
21 when you get to the NUREG, that you have got the  
22 calculations.

23 DR. KRESS: Yeah, I think that be worthwhile.

24 CHAIRMAN SHACK: Because some of the others are  
25 more -- you know, yes, they are important, but I think those

1 are readable.

2 DR. KRESS: I would like to see a little more of  
3 the technical basis behind your weighting factors for the  
4 three uncertainties. Those look a little arbitrary to me.  
5 Maybe that is all there is to them, but it left me a little  
6 cold.

7 MR. JONES: Well, what I heard during the break, I  
8 think part of what you see there is some of us have toiled  
9 in the nuclear analysis part of the industry for a long  
10 time, and what we were trying to do is say, what is a  
11 reasonable way to group these sources of uncertainty and  
12 weight them properly? Maybe that is just what is needed.  
13 But those of us toil in that nuclear, you know that a lot of  
14 that is experiential.

15 DR. KRESS: I understand, that is probably what it  
16 is.

17 MR. JONES: Right. So we will address that and  
18 try to do a good job with it.

19 DR. KRESS: Okay. I am pretty sure the question  
20 will come up, knowing the committee.

21 CHAIRMAN SHACK: Well, not if they don't discuss  
22 that comment, that is one way to get around it.

23 [Laughter.]

24 DR. KRESS: You're right, but George will find it.

25 DR. SEALE: We might may make him bring it up



1 anyway.

2 [Laughter.]

3 CHAIRMAN SHACK: That is enough then to give you a  
4 notion of what to bring for the hour-and-a-half.

5 MR. JONES: Okay.

6 DR. SEALE: Nick, was there anything else?

7 DR. TSOULFANIDIS: I was going to ask John  
8 something. The temperature of the moderator is important,  
9 of course, and it is not constant, even in the PWR, as you  
10 go up. Has this been addressed? It is lower at the bottom  
11 or at the top? The average, I recall is, what, .7 water  
12 density in the PWR, right? But does this produce an effect,  
13 did anybody look at that?

14 DR. CAREW: The guide raises these issues and  
15 states that you must account for the temperature, and we  
16 have looked at that. We looked at the temperature of the  
17 coolant, it enters several places. It enters in the  
18 downcomer temperature, and that is typically, that is an  
19 uncertainty that we have looked at in the uncertainty  
20 analysis. And, typically, when the temperature, the inlet  
21 temperature is used, the uncertainty in the inlet  
22 temperature contributes about 2 percent at the most to the  
23 uncertainty in the fluence, so it gets lost compared to the  
24 other larger uncertainties.

25 The temperature in the bypass region also is known

1 and also the uncertainty -- well, let me go back a step. In  
2 an operating plant, the uncertainty due to the measurement  
3 uncertainty in the inlet temperature, it contributes about  
4 1, probably 1 percent, 1-1/2 percent to the fluence  
5 uncertainty. Then there is a question, in each one of those  
6 regions, you have a distinct temperature, and, again, the  
7 absolute temperature -- across the core, there is maybe a 60  
8 degree temperature rise across the core, in the center of  
9 the core, and the peripheral bundles where it counts is  
10 maybe a 30 degree rise. So the uncertainty in that  
11 temperature is much smaller, or the effect of that is much  
12 smaller than the uncertainty in the downcomer where you have  
13 a much larger thickness of water and you have a larger --  
14 you have a significant uncertainty.

15 So the major contributor to those temperatures  
16 turns out to be relatively small, and it is swamped by the  
17 uncertainty in the source which typically could be 10  
18 percent. So you are comparing a 2 percent, a 1 percent  
19 uncertainty to an uncertainty in the source which is 10  
20 percent, you won't even see it.

21 That doesn't account for the uncertainties in the  
22 problem, the nuclear data uncertainties. Well, let me go  
23 back a step. The overall uncertainty in a good calculation  
24 nowadays may be of the order of like 15 percent. So you are  
25 going to add on or subtract a 1 or 2 percent uncertainty,

1 you will never see it. So, in practice, the temperatures  
2 really are not that important, but they are a consideration  
3 and we have looked at them.

4 DR. TSOULFANIDIS: One other source of uncertainty  
5 is if you take the pins in one assembly, they don't all have  
6 the same burnup. Therefore, if you look at them as a source  
7 of neutrons, they don't produce the same number of numbers.  
8 And this critical, as we know, for the last row of  
9 assemblies at the periphery of the core.

10 In the Monte Carlo calculation, you pointed out  
11 that you looked at the pins individually, if I understood  
12 you correctly, and, therefore, this neutron source was  
13 introduced into the Monte Carlo calculation based on pin by  
14 pin. I assume this was based on isotopics calculations.

15 DR. CAREW: Right.

16 DR. TSOULFANIDIS: How was this done with the  
17 deterministic code?

18 DR. CAREW: Okay. In the deterministic DORT  
19 calculation, we also included the exact same source, the  
20 exact same pin powers and the exact same exposure. So the  
21 same data went to both calculations. The only difference  
22 was that in the DORT calculation, that information had to be  
23 smeared and mapped onto an R theta geometry which distorted  
24 it. But we have a code that does that and the mesh on the  
25 periphery of those peripheral bundles is pretty fine. So we

1 get a pretty detailed, I mean if we have a 15 by 15 bundle  
2 on the core, we don't have a mesh of 15 by 15 in those  
3 peripheral bundles, but we have probably close to 200 mesh  
4 points in that, so it gets a pretty good representation.

5 DR. KRESS: I was fascinated by the fact that you  
6 could use a homogeneous calculation and get the same answers  
7 as a heterogeneous one. I don't suppose that is very  
8 surprising. But what are the implications of that? Does  
9 that help you make the calculations easier or does it help  
10 somebody do it a lot faster, or does that help any?

11 DR. CAREW: Yeah, I was amazed also, kind of  
12 disappointed in a way. But it may be due to -- we are  
13 looking at fast neutrons, I don't see that detail they are  
14 going so fast. They have scattering events that occur like  
15 every six inches or something like that.

16 DR. KRESS: It is the scattering that makes it  
17 different.

18 DR. CAREW: So they don't see that detail. But it  
19 makes a big, a very, very big simplification. It means that  
20 in the DORT calculation, where you really can't represent it  
21 explicitly, that DORT calculation does a good job, and that  
22 is what we see.

23 DR. KRESS: That explains why the DORT does a good  
24 job.

25 DR. CAREW: Exactly.

1 DR. KRESS: That is the implication of that.

2 DR. CAREW: Right. Yes. I thought we might give  
3 it streaming, some kind of streaming effect, but it didn't  
4 occur. We don't have it.

5 DR. KRESS: You might want to bring that detail  
6 out a little more when you show that particular slide.

7 DR. CAREW: Okay.

8 CHAIRMAN SHACK: Is your smearing code described  
9 in a NUREG, I mean is that -- that would seem like an  
10 important input to these kinds of calculations, just how  
11 that smearing is done.

12 DR. CAREW: Well, you mean the mapping code?

13 CHAIRMAN SHACK: Yeah.

14 DR. CAREW: There are several different mapping  
15 codes out there. We have a code that is referenced in the  
16 Reg. Guide and there are different codes that do that same  
17 job.

18 CHAIRMAN SHACK: Have you looked at the  
19 sensitivity of the calculation to those mapping codes?

20 DR. CAREW: Well, let me go back a step, give you  
21 some perspective. The effect of all that detail on the  
22 periphery is worth about maybe 7 or 8 percent to the vessel  
23 fluence. It is not an enormous effect, but it goes -- I  
24 mean it helps, it reduces the fluence, so it is worth going  
25 after. So we are talking about only, you know, it is a 7 or

1 8 percent effect. So you are not going to -- we have a  
2 requirement in the Reg. Guide that the peripheral bundle  
3 should be represented in such a way that the area of the  
4 peripheral bundle is represented in the R theta mesh, is  
5 good to half a percent. So we require an accurate modeling  
6 of that peripheral boundary.

7 And I don't know that you have to put in each pin  
8 explicitly. You probably could get by with a coarser  
9 representation, and it is probably not really not necessary  
10 probably. If the neutrons aren't seeing a difference  
11 between the void fraction inside or outside the bundle, they  
12 are probably not going to see whether it is the second or  
13 third row in pin.

14 CHAIRMAN SHACK: If there are no further  
15 questions, I believe we can bring the subcommittee meeting  
16 to an end. It was a very good presentation, I enjoyed it  
17 very much.

18 [Whereupon, at 11:38 a.m., the meeting concluded.]  
19  
20  
21  
22  
23  
24  
25

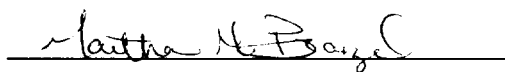
REPORTER'S CERTIFICATE

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

NAME OF PROCEEDING:        MATERIALS & METALLURGY SUBCOMMITTEE  
                                 MEETING  
                                 (ACRS)

CASE NO:

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



Jon Hundley

Official Reporter

Ann Riley & Associates, Ltd.

ADVISORY COMMITTEE ON REACTOR SAFEGUARDS  
MATERIALS AND METALLURGY SUBCOMMITTEE  
CALCULATION OF NEUTRON FLUENCE DG-1053

TH, NOVEMBER 16, 2000  
ROCKVILLE, MARYLAND

ROOM T2-B3

**- PROPOSED AGENDA -**

<u>TOPIC</u>	<u>PRESENTER</u>	<u>TIME</u>
I. Opening Remarks	W. Shack, ACRS	8:30-8:35 a.m.
II. Introductory Remarks	N. Chokshi, RES	8:35-8:45 a.m.
III. Overview and Status of DG-1053	J. Carew, BNL	8:45-9:45 a.m.
<b>- BREAK -</b>		9:45-10:00 a.m.
IV. Review of Industry Comments	J. Carew, BNL	10:00-11:00 a.m.
V. Review of NUREG/CR-6115, "Pressure Vessel Fluence Calculation Benchmark Problems and Solutions"	J. Carew, BNL	11:00-11:30 a.m.
VI. Discussion	W. Shack, ACRS	11:30-12:00 noon
VII. Adjournment	W. Shack, ACRS	12:00 noon

**NOTE:**

Presentation time should not exceed 50 percent of the total time allotted for specific item. The remaining 50 percent of the time is reserved for discussion.

Number of copies of the presentation materials to be provided to the ACRS - 25.



INTRODUCTORY STATEMENT BY THE CHAIRMAN OF THE  
MATERIALS AND METALLURGY SUBCOMMITTEE  
11545 ROCKVILLE PIKE, ROOM T-2B3  
ROCKVILLE, MARYLAND  
NOVEMBER 16, 2000

The meeting will now come to order. This is a meeting of the ACRS Subcommittee on Materials and Metallurgy . I am Dr. William Shack, Chairman of the Subcommittee.

ACRS Members in attendance are Thomas Kress and Robert Seale. Also in attendance is ACRS Consultant Nicholas Tsoulfanidis.

The purpose of this meeting is for the Subcommittee to hear presentations by the staff concerning the proposed final regulatory guide on calculational and dosimetry methods for determining pressure vessel neutron fluence. 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. Noel Dudley 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 October 25, 2000.

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

We have received no written comments. A representative of Framatone requested the opportunity to make a statement at the end of the meeting.

The ACRS examined draft regulatory guide DG-1025, "Calculational and Dosimetry Methods for Determining Pressure Vessel Neutron Fluence," in 1993 and requested the opportunity to review the proposed final version after public comments were reconciled. Subsequently, DG-1025 evolved into DG-1053. The staff briefed this Subcommittee on the status of DG-1053 during its April 15-16, 1997 meeting. More recently, DG-1053 evolved into the proposed final regulatory guide we are reviewing today. During this evolutionary process stakeholders had opportunities to provide comments on the different versions of the regulatory guide.

Today we will hear a presentations regarding the proposed final regulatory guide. We will now proceed with the meeting and I call upon Dr. Nilesh Chokshi, Chief of the Materials Engineering Branch, to begin.

# **ADVISORY COMMITTEE ON REACTOR SAFEGUARDS MATERIALS AND METALLURGY SUBCOMMITTEE**

## **CALCULATION OF NEUTRON FLUENCE REGULATORY GUIDE**

---

Dr. Nilesh Chokshi, Chief  
Materials Engineering Branch  
Division of Engineering Technology  
Office of Nuclear Regulatory Research

301-415-6013

U.S. NRC Office of Nuclear  
Regulatory Research  
Division of Engineering Technology  
Materials Engineering Branch



# **Purpose of Presentation**

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- To Discuss Final Version of the Regulatory Guide
- To Discuss Disposition of Public Comments
- To Seek ACRS Approval to Issue the Final Regulatory Guide



# Need for Regulatory Guide

- Provide Standardized Methods and Procedures for Fluence Calculations and Use of Vessel Dosimetry
- Wide Variety of Application of Existing Methods for Determining Fast Neutron Flux
- Comply with Regulations on Reactor Pressure Vessel Integrity



# Status of Regulatory Guide

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- Initial Efforts Started in 93
  - Publication of 2 Drafts
  - 3 Rounds of Public Comments
  - 3 Public Meetings
  - 5/00 - Latest Round of Comments Received
- 11/00 -Appropriate Comments Incorporated
- Plan to Publish Early 2001



# Presentation Outline

- Overview of the Guide

William Jones, NRC

- Guide Technical Details

Dr. John Carew, BNL

- Summary and Schedule

William Jones, NRC



# **ADVISORY COMMITTEE ON REACTOR SAFEGUARDS MATERIALS AND METALLURGY SUBCOMMITTEE**

## **CALCULATION OF NEUTRON FLUENCE REGULATORY GUIDE**

---

William Jones  
Materials Engineering Branch  
Division of Engineering Technology  
Office of Nuclear Regulatory Research

301-415-7558

U.S. NRC Office of Nuclear  
Regulatory Research  
Division of Engineering Technology  
Materials Engineering Branch





# Introduction

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- Objectives of Regulatory Guide
- Contents of Regulatory Guide

U.S. NRC Office of Nuclear  
Regulatory Research  
Division of Engineering Technology  
Materials Engineering Branch



# **OBJECTIVES OF REGULATORY GUIDE**

## **PROVIDE:**

- **METHODS FOR FLUENCE CALCULATION AND USE OF DOSIMETRY FOR DETERMINING RPV NEUTRON FLUENCE THAT SATISFY REGULATIONS.**
- **DESCRIPTION OF FLUENCE CALCULATION METHODS**
- **USE OF DOSIMETRY MEASUREMENTS FOR VALIDATION OF CALCULATIONS**
- **PROCEDURES FOR QUALIFICATION OF CALCULATIONS & DETERMINATION OF UNCERTAINTY**
- **MEASUREMENT PROCEDURES**

U.S. NRC Office of Nuclear  
Regulatory Research  
Division of Engineering Technology  
Materials Engineering Branch



# CONTENTS SUMMARY

- **FLUENCE CALCULATION METHODS**

- Input Data

- Materials & Geometry

- Cross-Sections

- Neutron Source

- Fluence Calculation

- Qualification & Uncertainty

- **DOSIMETRY**

- Procedures

- Dosimeters

- Measurement Uncertainties

- Validation

- Fluence Estimates Based on Measured Data

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Regulatory Research  
Division of Engineering Technology  
Materials Engineering Branch

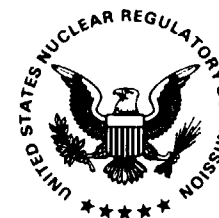


# CONTENTS SUMMARY

(CONTINUED)

- **REPORTING**
  - Methods
  - Calculation vs Measurement
- **IMPLEMENTATION**

U.S. NRC Office of Nuclear  
Regulatory Research  
Division of Engineering Technology  
Materials Engineering Branch



# Summary

- Detailed Information on Fluence Calculation and Measurement Methods
- Benchmark Calculations in NUREG/CR-6115
- Extensive Review and Substantial Public Participation
- Believe Regulatory Guide is Ready for Final Publication
- Full ACRS Committee Meeting Planned for 12/7/00
- Publish Early 2001

U.S. NRC Office of Nuclear  
Regulatory Research  
Division of Engineering Technology  
Materials Engineering Branch



**ADVISORY COMMITTEE ON REACTOR SAFEGUARDS  
MATERIALS AND METALLURGY SUBCOMMITTEE  
CALCULATION OF NEUTRON FLUENCE DG-1053**

---

**Presented by  
John Carew**

**Energy and Nuclear Technology Division  
Department of Energy Science and Technology  
Brookhaven National Laboratory  
November 16, 2000**

**ADVISORY COMMITTEE ON REACTOR SAFEGUARDS  
MATERIALS AND METALLURGY SUBCOMMITTEE  
CALCULATION OF NEUTRON FLUENCE DG-1053**

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**Presented by  
John Carew**

**Energy and Nuclear Technology Division  
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Brookhaven National Laboratory  
November 16, 2000**

# Background

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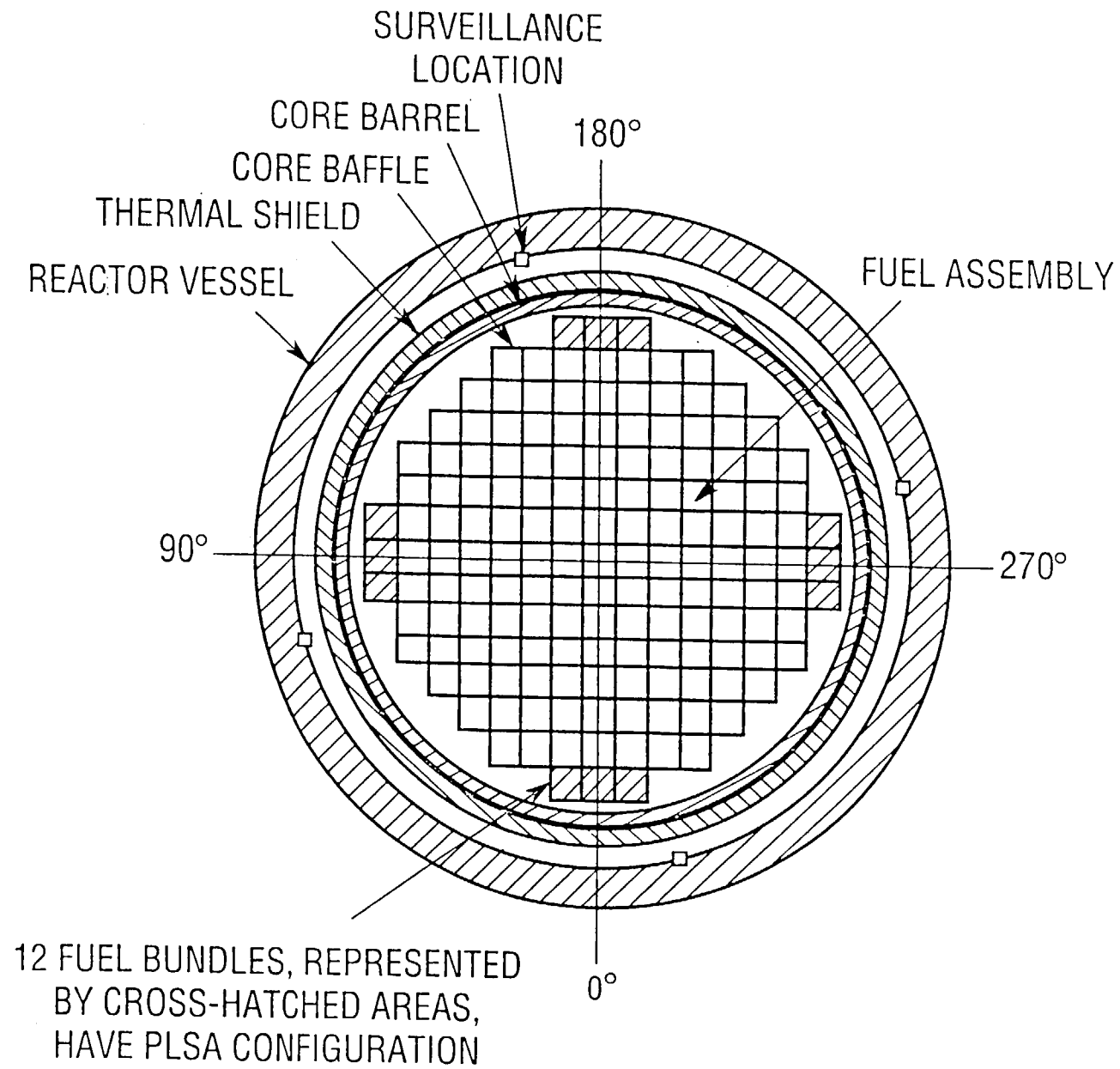
- Reactor Pressure Vessel Fluence is Required for Determination of Vessel Embrittlement and Lifetime
- Vessel Fluence is used to Determine the Adjusted Reference Temperature for the Nil-Ductility Transition  $RT_{NDT}$
- The “PTS Rule”, 10 CFR PART 50.61, Requires the Determination of the Fluence for  $RT_{PTS}$

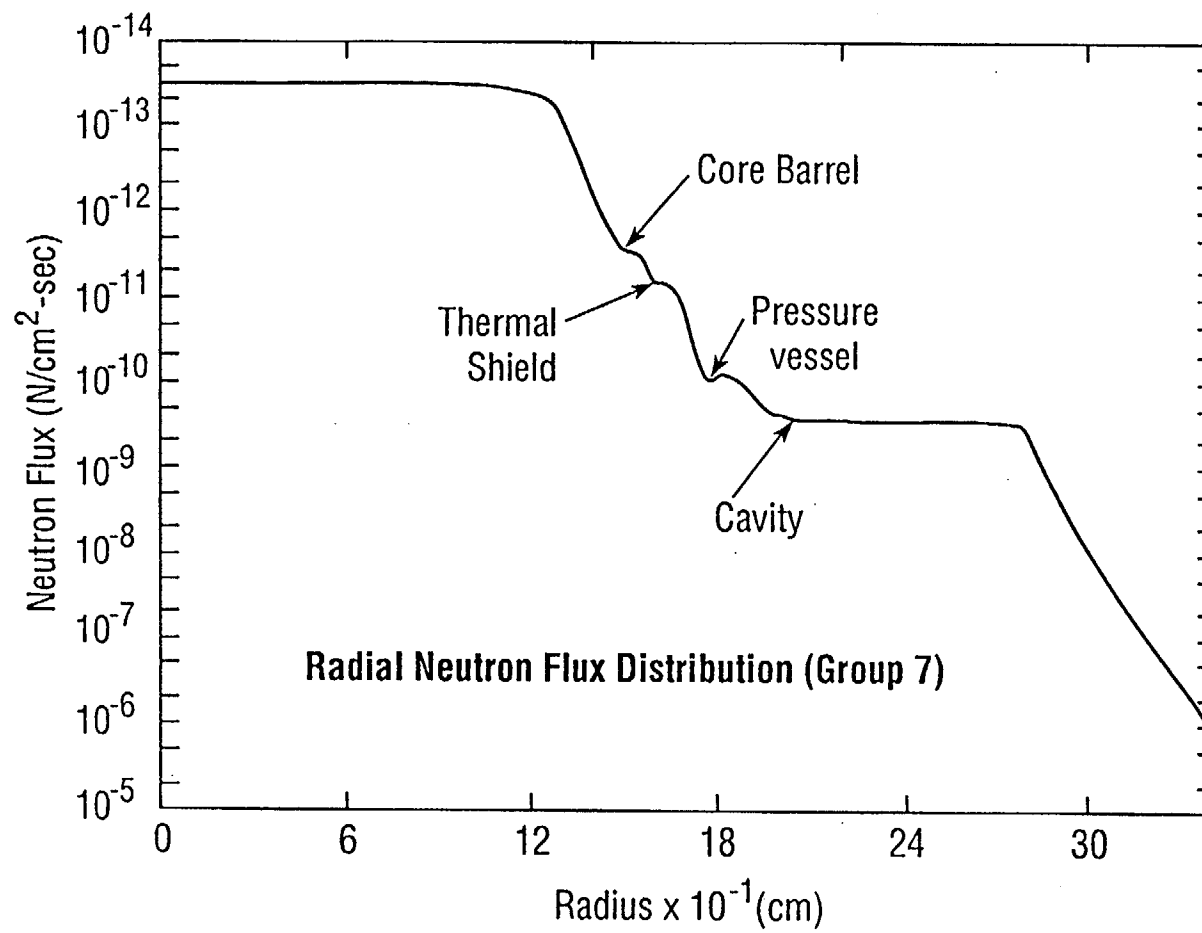


# Background

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- Neutron Fluence Undergoes Several Decades of Attenuation Between the Core and Vessel
- Fluence Calculation is Therefore Sensitive to
  - Material and Geometry Representation of the Core and Vessel Internals
  - Space/Energy Neutron Source
  - Transport Calculation Numerical Schemes
- Detailed Multigroup/Multidimensional Analysis is Required for an Accurate Fluence Estimate





# Background

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- Wide Range of Fluence Methods are used:  
Cross Section Sets, Physics Approximations  
(Source and Axial Treatment) and Codes
- Limited Number and Uncertainty of Capsule  
Benchmark Data
- For Certain Vessels Limited EOL Margin to  
 $RT_{PTS}$  Limits

# Presentation Overview

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- Review Regulatory Guide DG-1053
- Resolution of Industry Comments on DG-1053
- PWR and BWR Pressure Vessel Benchmark Problems - NUREG/CR-6115

# Regulatory Guide DG-1053

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## ■ Developed

- For - Materials Engineering Branch  
Division of Engineering Technology  
Office of Nuclear Regulatory Research
- By - Brookhaven National Laboratory
  - National Institute of Standards and Technology
  - Oak Ridge National Laboratory

# Summary of Regulatory Guide DG-1053

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## ■ Purpose

- Document calculation and measurement methods for determining pressure vessel fluence that are acceptable to NRC

## ■ Scope

- Vessel fluence determination for input to CRF 50.61  $RT_{PTS}$ , input to Regulatory Guide 1.99 and Appendix-G

# Summary of Regulatory Guide DG-1053

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## ■ Includes

- Detailed description of fluence calculation and measurement methods
- Procedures for qualification of calculations and measurements
- Table of specific modeling, dosimetry, qualification and reporting requirements
- Requires calculation of NUREG/CR-6115 pressure vessel fluence benchmark problems for methods qualification



# Summary of Regulatory Guide DG-1053

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## ■ Primary Calculational Tasks

- Determination of Geometrical and Material Composition Data
- Determination of the Core Neutron Source
- Transport Theory Calculation of the Neutron Flux from Core to Vessel and Cavity

# Discrete Ordinates Calculation Methodology

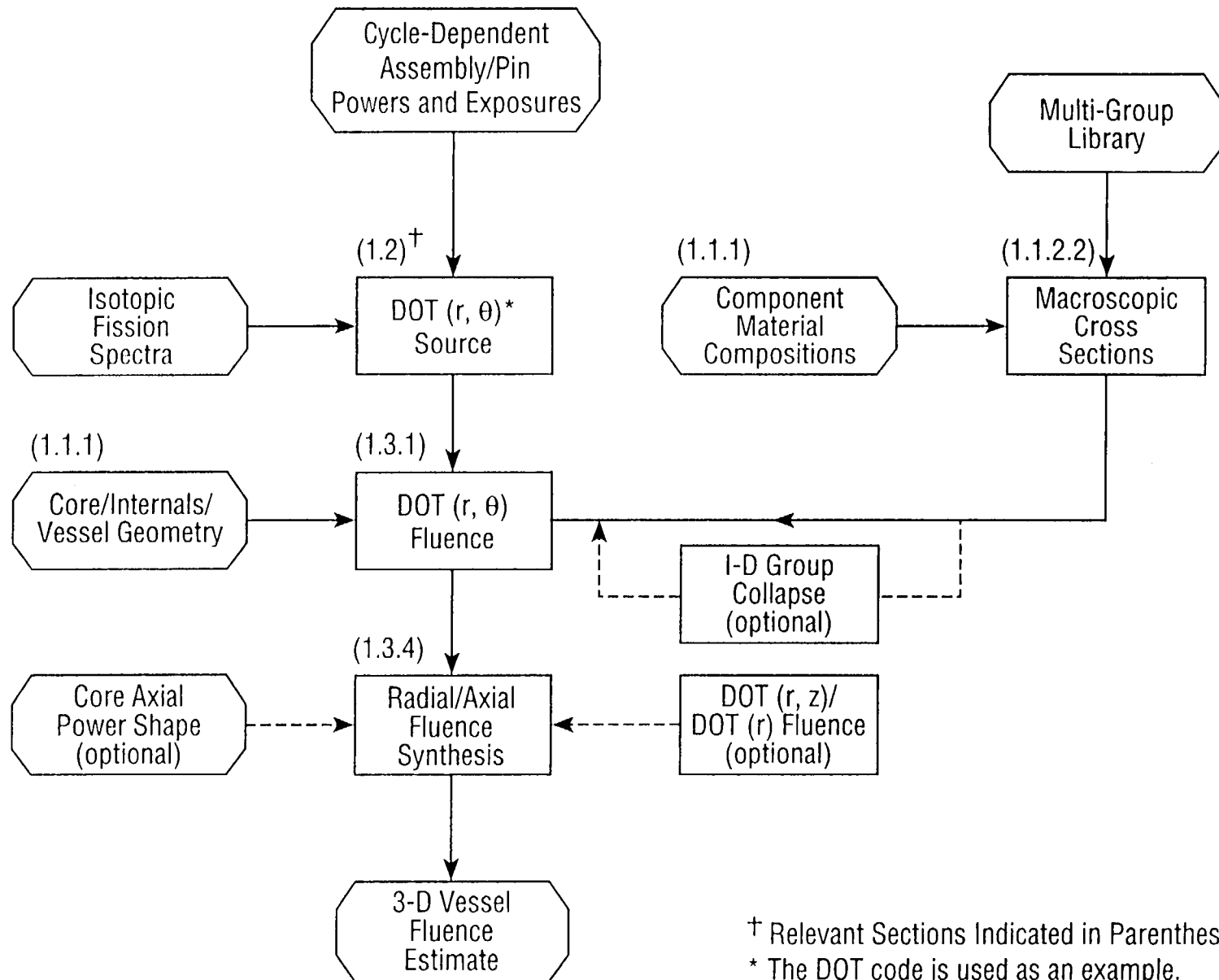
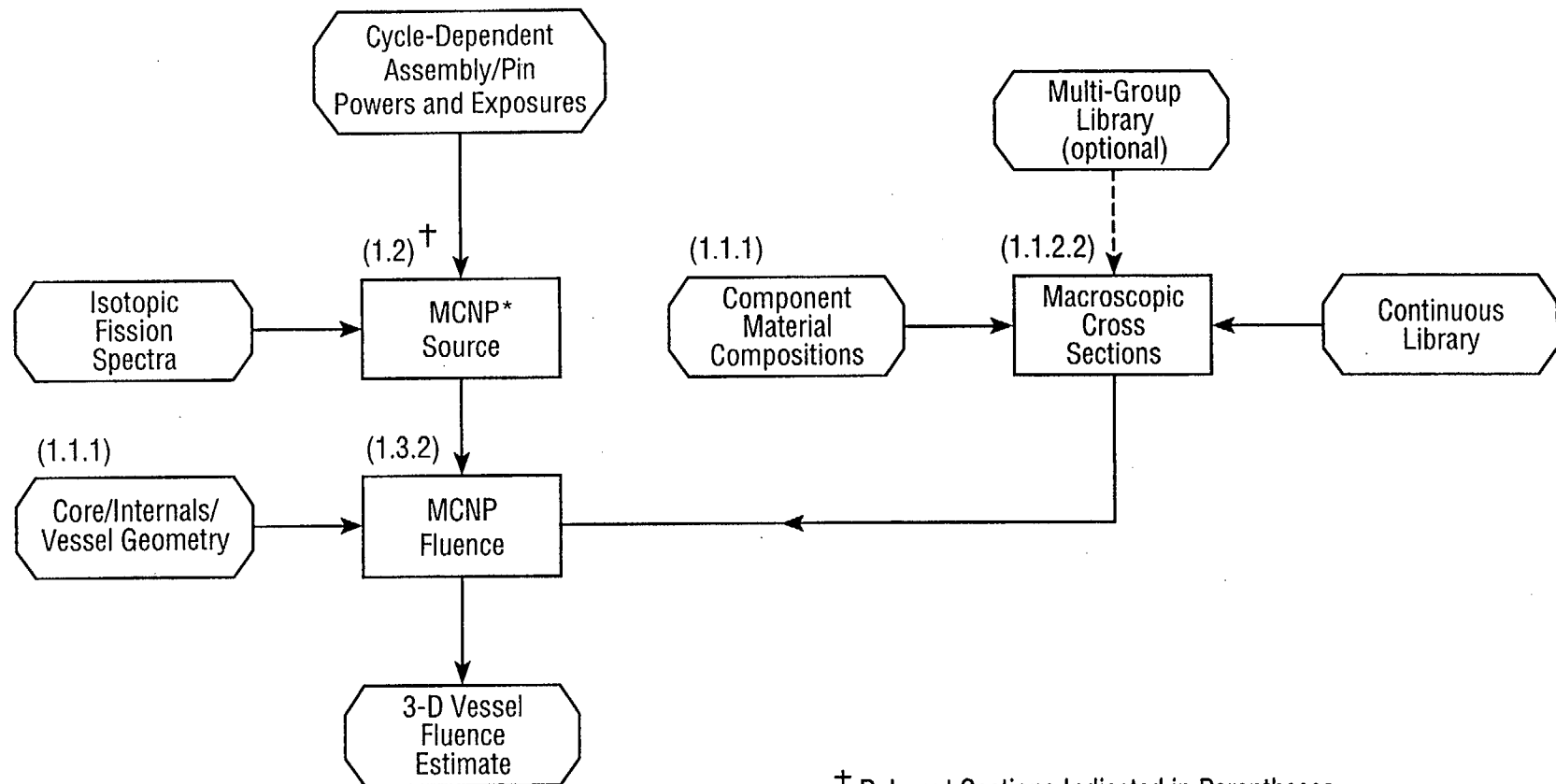


FIGURE 1

# Monte Carlo Calculation Methodology

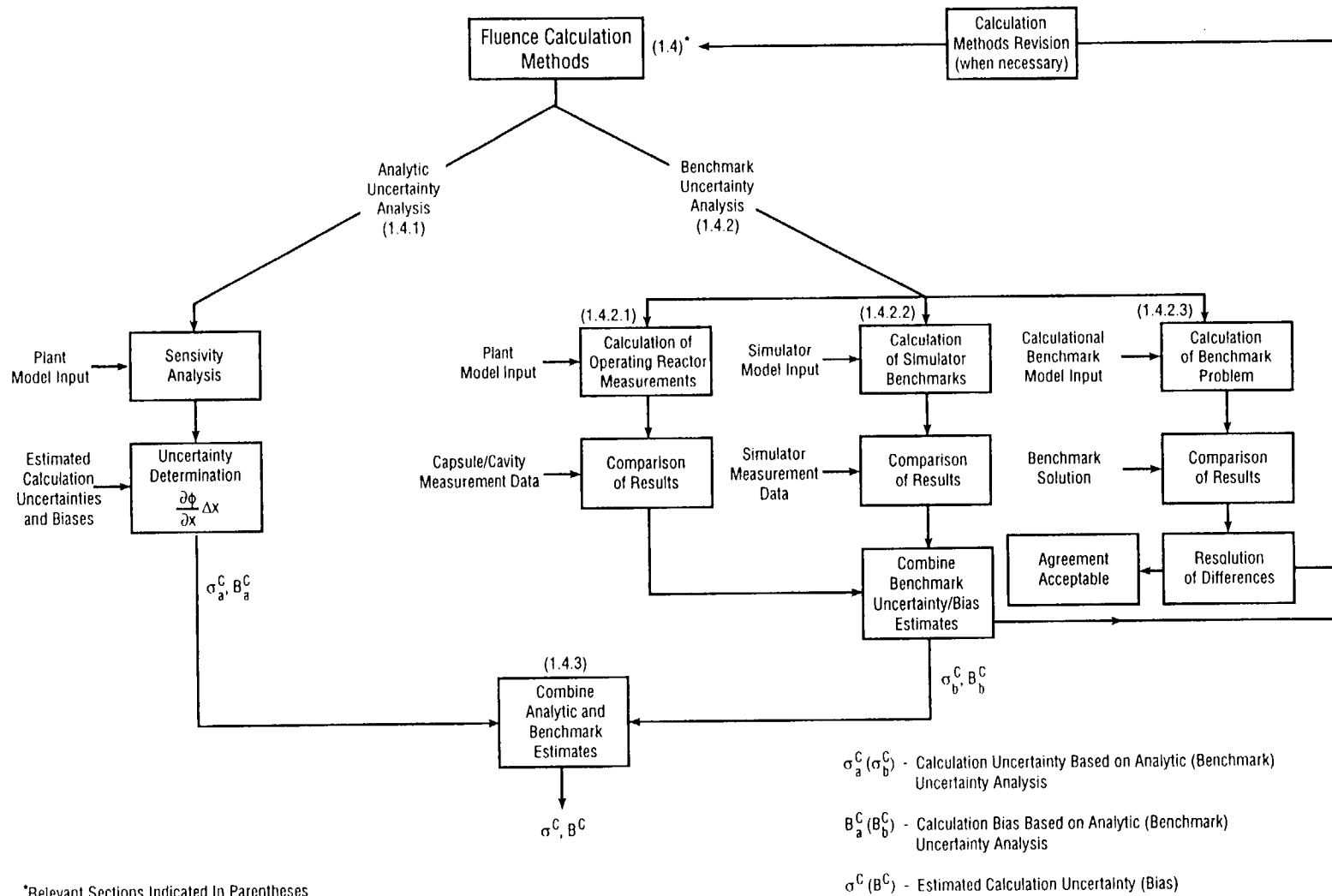


† Relevant Sections Indicated in Parentheses.

\* The MCNP code is used as an example.

FIGURE 2

# Calculation Methodology · Qualification Procedure



\*Relevant Sections Indicated In Parentheses

FIGURE 3

# Fluence Determination

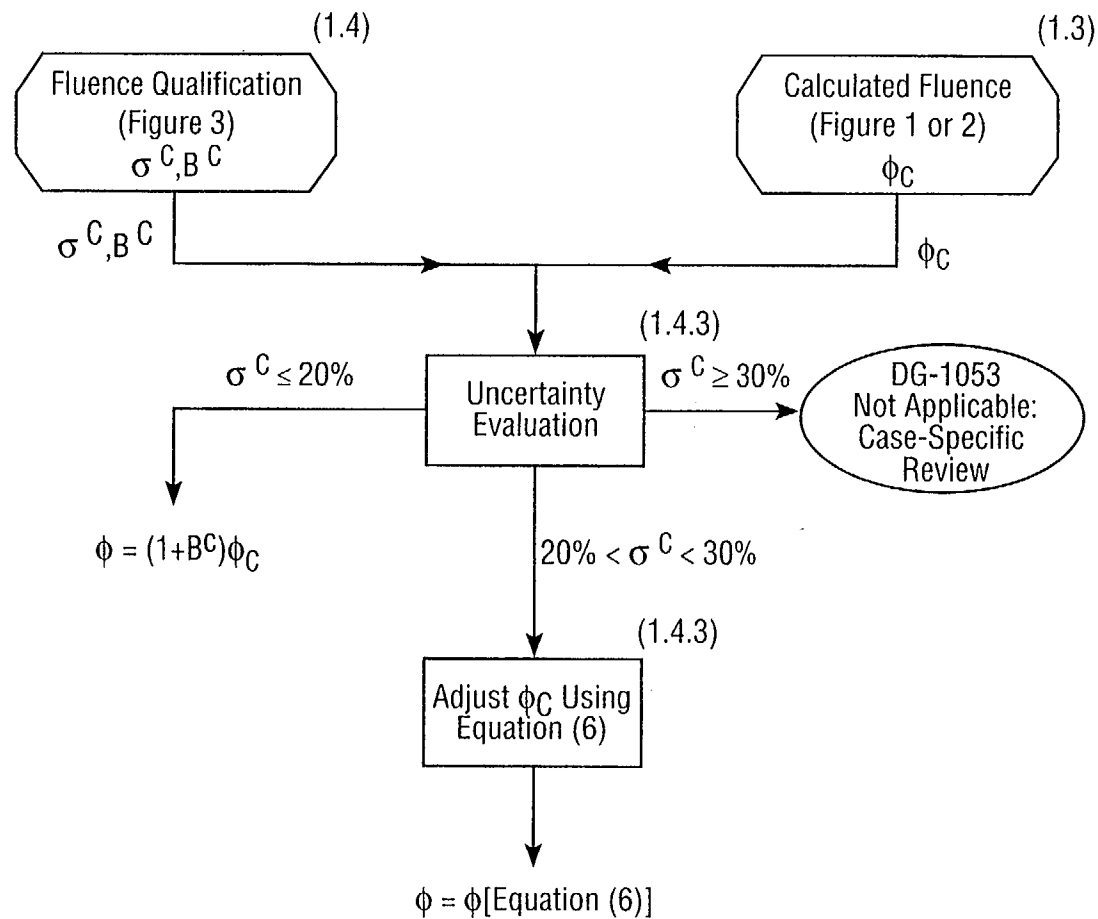


FIGURE 4

# Measurement Qualification Procedure

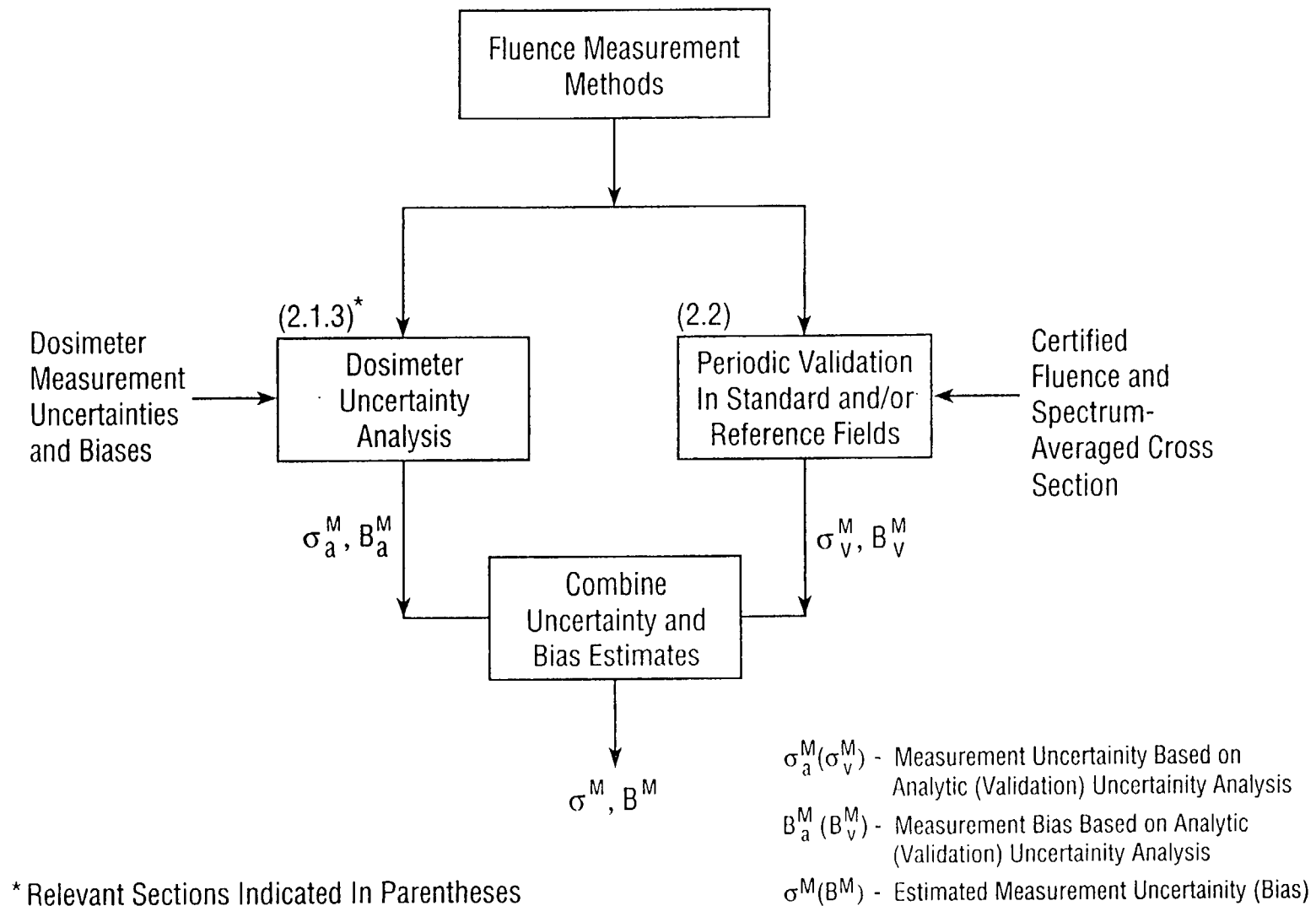


Figure 5

# Summary of Regulatory Guide DG-1053

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## ■ Fluence Calculational Methods

- Best-Estimate Rather Than Bounding Approach
- Provides Accuracy of  $< 20\%$  ( $1-\sigma$ )
- Energy Range from 15 MeV to 0.1 MeV

## ■ Qualification Via Benchmarking and Uncertainty Analysis

# Summary of Regulatory Guide DG-1053

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## ■ Applicability

- Fluence Input for Appendix-G and Reg. Guide 1.99
- Both PWR and BWR Core/Vessel Geometries and Fuel Designs
- Vessel Fluence Reduction Designs (PLSAs, Low-Leakage Cores, etc.) and Life Extension Calculations



# Status of Regulatory Guide DG-1053

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- NRC Pre-Release Reviews (1993)
  - ACRS Subcommittee
  - ACRS Committee
  - CRGR
- NRC Release for Comment
- Formal Review Meeting with Industry
- Round-1 Industry Comments Evaluated and Incorporated where Appropriate

# Status of Regulatory Guide DG-1053

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- September 18, 1996 Meeting with Industry to Review DG-1053
- Round-2 Industry Comments Evaluated and Incorporated where Appropriate
- Incorporation of Monte Carlo Transport Methods and BWR Benchmark Problem in DG-1053 and NUREG-6115
- September 28, 1999 NRC/Industry Meeting to Review DG-1053

# Status of Regulatory Guide DG-1053

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- September 28, 1999 - Industry Requests Resolution of Comments Document (RCD) which Provides Basis for Resolution of Previous Comments
- March 2000 - Resolution of Comments Document Provided for Stakeholders Review
- May 2000 - Industry Comments on DG-1053 Received
- August 2000 - Evaluation of Industry Comments Completed and Appropriate Changes Incorporated in DG-1053
- Early 2001 - Final Release of Regulatory Guide

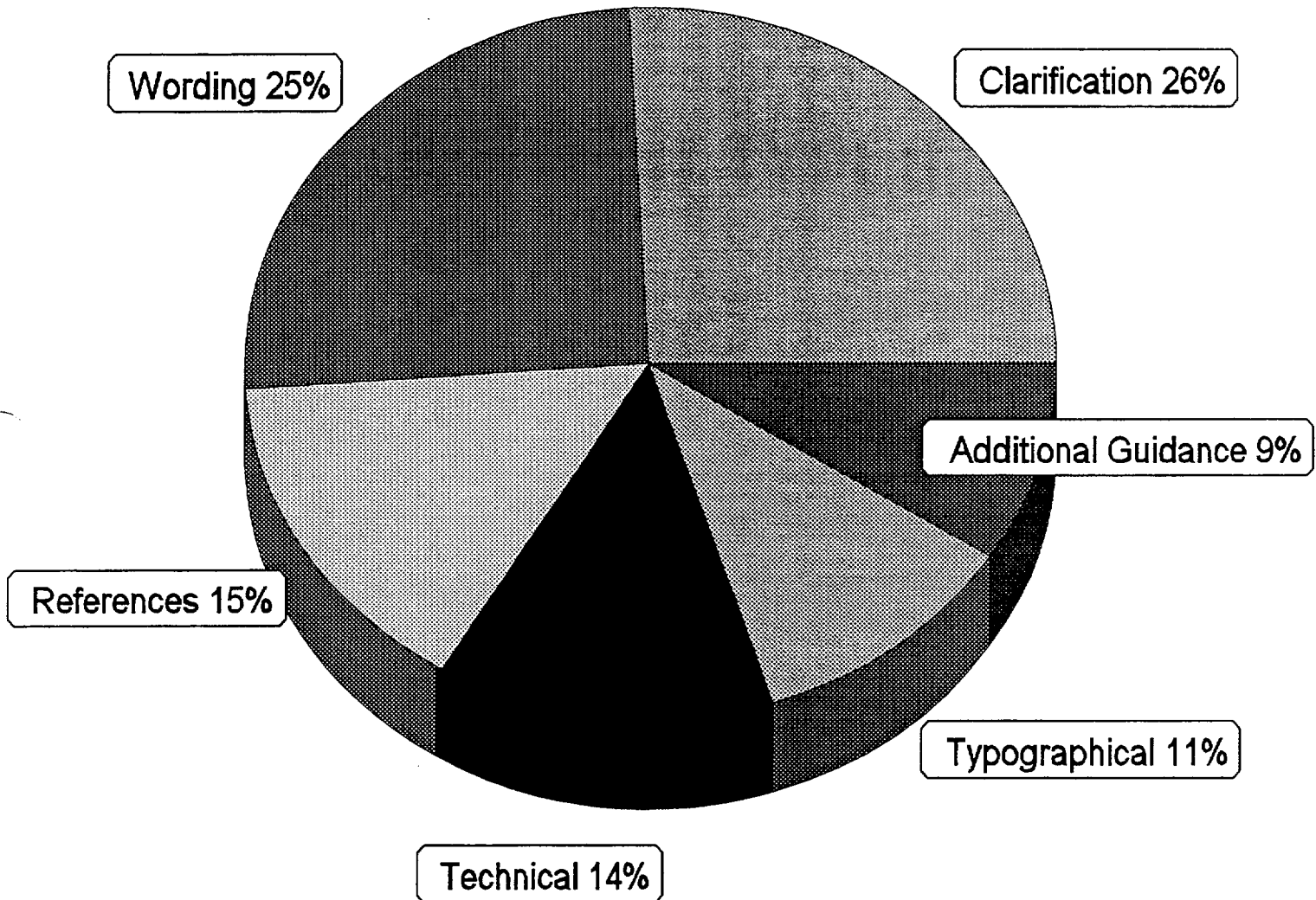
# Resolution of DG-1053 Comments

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## ■ Resolution of Comments

- Comments from: NEI, PSU (A. Haghighat), Bechtel Power (W. C. Hopkins) and DWM
- Concerned editing, organization, methods and qualification
- Includes recommendations to both relax and tighten requirements
- Response to all comments and decision basis
- Response based on Team consensus
- Resulting changes and additions included in DG-1053

# COMMENT TYPES



# Resolution of DG-1053 Comments

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## ■ Comment Resolution Approach

- All comments thoroughly evaluated for possible inclusion
- Requirements for inclusion
  - Consistent with scope and purpose
  - Technically valid
  - Significant part of fluence determination
  - Consistent with presently accepted methods
  - Level of detail not overly prescriptive and should allow sufficient freedom to apply engineering judgement
- Response based on Team consensus
- Resulting changes/additions included in DG-1053

**RESPONSES TO THE GENERAL COMMENTS PROVIDED BY THE  
NUCLEAR ENERGY INSTITUTE**

1) Comment: The final version of NUREG-6115 should be released.

2) Comment: NEI recommends a standard problem round robin exercise among the NRC contractor and industry participants using the draft regulatory guide.

1) Response: The draft version of NUREG/CR-6115 was released in September 1999. The final version of NUREG/CR-6115 will be published in early calendar 2001.

2) Response: The proposed round robin is outside the scope of the DRG-1053.

The Guide provides highly detailed guidance on the methods for measuring and calculating fast neutron fluence which satisfy the requirements of both Appendix-G to Part 50 and 10 CFR 50.61.

These methods have been employed in several measurement benchmark analyses which have been referenced and are publicly available. The NUREG/CR-6115 Benchmark Problem calculations will be available in early calendar 2001.

## RESPONSES TO THE COMMENTS PROVIDED BY THE NUCLEAR ENERGY INSTITUTE

1) Comment: The Resolution of Comments Document includes responses with insights that would be beneficial to the user of the Guide. Specifically Responses IV.8.3, IV.10.3, V.42.3, VI.16.3, VIII.5.3, VIII.12.3 and IX.3.3.

6) Comment: The Guide should include a reference to ASTM Standard E693 for characterizing neutron exposures of iron and low alloy steels in terms of displacements per atom (dpa), ASTM Standard E-2005 for benchmark testing and ASTM Standard E-1018 for the selection of dosimetry cross sections.

1) Response: Responses IV.8.3, IV.10.3 have been added to the Guide. Responses V.42.3 and VIII.5.3 were included as part of a previous update. Responses VI.16.3, VIII.12.3 and IX.3.3 are considered too detailed and/or are outside the scope of the Guide and are not being included

6) Response: The references for these ASTM standards have been added.



## RESPONSES TO THE COMMENTS PROVIDED BY THE NUCLEAR ENERGY INSTITUTE

Comments	Responses
<p>18) <u>Comment</u>: The Monte Carlo energy bin structure for determining the dosimeter response should satisfy the same requirements as the broad multi-group energy structure given in Regulatory Position 1.1.2.</p>	<p>18) <u>Response</u>: The text has been revised to state that "to insure an accurate integration over the dosimeter cross section, the energy bin structure used to determine dosimeter response scoring should satisfy the requirements of Regulatory Position 1.1.2 concerning the selection of the multi-group library group structure."</p>
<p>21) <u>Comment</u>: The statistical acceptance criteria presented are generally specific to the MCNP Monte Carlo code and should be presented as an example rather than as a minimum set of criteria.</p>	<p>21) <u>Response</u>: The wording in the Guide has been changed to indicate that the statistical criteria are a representative set rather than a minimum set.</p>

## RESPONSES TO THE COMMENTS PROVIDED BY THE NUCLEAR ENERGY INSTITUTE

27) Comment: (a) Additional guidance should be provided indicating how the uncertainty estimates based on the operating reactor measurements and the simulator benchmarks are to be combined to determine the fluence uncertainty estimate.

27) Response: (a) "Because the weighting of the analytic and benchmark uncertainty estimates depends on the details of the specific application which can vary widely, it is not possible to specify a practical and generically valid prescription for determining the weights. However, the following example illustrates factors that should be considered. In the case where as-built measurements of the vessel diameter are available and reasonable estimates of the core neutron source and other input uncertainties can be determined, the analytic uncertainty estimate should be very reliable and its weight may be increased to  $w_A = 0.5$ . If, in addition, there are a substantial number ( $> 10$ ) of accurate ( $\sigma < 5\%$ ) operating reactor measurements, the weighting of the uncertainty estimate based on this data may be set to  $w_O = 0.3$ . The weighting of the uncertainty estimate based on the vessel simulator measurements is then  $w_S = 0.2$ ."

**RESPONSES TO THE COMMENTS PROVIDED BY THE  
NUCLEAR ENERGY INSTITUTE**

27) Comment: (b) Additional guidance on how the calculation of the benchmark problem will be used to determine the fluence uncertainty should be provided.

27) Response: (b) As suggested, the benchmark problem calculation will be used as a "go/no-go" test rather than as an estimate of the fluence uncertainty. The text of Section 1.4.2.3 has been modified to reflect this change.

32) Comment: The analytic uncertainty analysis requires that model parameter sensitivity calculations be performed. The Guide states that, in some cases, the Monte Carlo sensitivity calculations will require that the change in the model parameter be increased to provide a reliable estimate of the sensitivity. Also, since the sensitivities are not generally linear, additional calculations may be required to determine the nonlinear dependence of the sensitivity.

32) Response: Additional text has been added noting that the dependence of the sensitivity on the perturbed parameter may not be linear and, if the parameter is significantly outside the parameter one-sigma standard deviation, several calculations may be required to determine the nonlinear dependence of the sensitivity.

**RESPONSES TO THE COMMENTS PROVIDED BY THE  
NUCLEAR ENERGY INSTITUTE**

<b>Comments</b>	<b>Responses</b>
<p>37) <u>Comment</u>: (a) While guidance on the agreement between measured and calculated integral quantities is provided, no guidance on the expected agreement for group fluxes is given.</p> <p>(b) DG-1053 does not define the bias.</p>	<p>37) <u>Response</u>: (a) The requirement to compare measured and calculated group fluxes has been removed.</p> <p>(b) A reference for the bias has been added to Footnote-1.</p>

**RESPONSES TO THE COMMENTS PROVIDED BY THE  
NUCLEAR ENERGY INSTITUTE**

37) Comment: (c) More information is required on the level of detail required for benchmark analysis.

37) Response: (c) The benchmark analysis of Section 1.4 requires the calculation of (1) a pressure vessel simulator (e.g., the PCA or PSF measurements) (2) operating reactor dosimetry measurements (either in-vessel, cavity or both) and (3) the NUREG-6115 benchmark. References 65, 72 and 73 provide several examples of benchmark analyses. References 74, 75 and 79 have been added to provide additional examples of benchmark analyses. Calculations of operating reactor dosimetry are well known throughout the industry and are performed for both in-vessel capsules and cavity measurements. Analyses of the benchmark problems are documented in NUREG-6115. The information provided in the references cited in the Guide is considered sufficient detail for performing benchmark analyses.

## RESPONSES TO THE COMMENTS PROVIDED BY THE NUCLEAR ENERGY INSTITUTE

40) Comment: (a) The referenced simulator benchmarks (References 5, 44, 58-63) and the calculation benchmark (NUREG-6115) do not provide sufficient detail to perform the benchmark calculations.

(c) There are no results available that use the DG-1053 method.

(d) BUGLE-96 is the latest version of the BUGLE cross section data and DOORS is the latest version of the DORT program. These versions of the nuclear data and transport code should be used to analyze the NUREG-6115 benchmark problem.

40) Response: (a) The NUREG-6115 report provides a complete definition of the benchmark problem except for the neutron source which is provided on a separate computer disc. References 74, 75 and 79 have been added to complete the documentation of the benchmarks.

(c) The NUREG-6115 Report includes benchmark results that have been determined using the DG-1053 method.

(d) The codes and nuclear data are being updated continuously. Changes included in the BUGLE-96 nuclear library and the DOORS code are presently being evaluated. If these changes have a significant effect on the application of the NUREG-6115 benchmark problems and there is a need to issue a revision to NUREG-6115, this will be considered.

**RESPONSES TO THE COMMENTS PROVIDED BY THE  
NUCLEAR ENERGY INSTITUTE**

40) Comment: (b) Additional guidance on the use of NUREG-6115 in qualifying the calculational methods and what constitutes an acceptable solution should be provided.

40) Response: (b) The following guidance has been added: "The calculation of the benchmark problems allows a detailed assessment and verification of the numerical procedures, code implementation, and the various modeling approximations relative to state-of-the-art solutions for representative operating configurations. If the differences between the benchmark problem calculation and the reference solution are substantially larger than what would be expected based on the differences in the methods approximations and nuclear data used in the two calculations, the agreement is considered unacceptable. In this case, the calculation should be reviewed and the differences between the two solutions explained. When the cause of the deviation is determined to be an error in the calculation, the calculational method must be revised."

## RESPONSES TO THE COMMENTS PROVIDED BY THE NUCLEAR ENERGY INSTITUTE

40) Comment: (e) In addition to the solutions calculated with DORT and MCNP, the NUREG-6115 Report should provide reference solutions calculated with different codes such as TWODANT and MCBEND.

(f) If the purpose of performing the NUREG-6115 benchmark calculations is to validate the implementation of DORT, the DORT electronic input and output files should be provided to insure that the modeling parameters are the same as used in NUREG-6115.

40) Response: (e) While the use of the TWODANT and MCBEND codes will provide an indication of the code-to-code variation, in view of the extensive benchmarking and testing of these codes, the uncertainty introduced by the code selection is very small when compared to the uncertainty in the plant fluence calculations. Consequently, the use of the DORT and MCNP codes in performing the calculations of NUREG-6115 is considered adequate.

(f) The purpose of the NUREG-6115 benchmark calculations is to validate both the implementation of DORT and the fluence calculation modeling techniques. Providing the DORT electronic files would prevent the validation of the modeling techniques which is considered to be most important.



**RESPONSES TO THE COMMENTS PROVIDED BY THE  
NUCLEAR ENERGY INSTITUTE**

Comments	Responses
<p>51) <u>Comment</u>: The term "every few years" in the statement "to ensure long-term consistency and to confirm measurement uncertainty, dosimetry measurements must be performed <u>every few years</u> in well characterized neutron fields," should be quantified.</p> <p>55) <u>Comment</u>: The guidance conflicts with the least-squares approach.</p>	<p>51) <u>Response</u>: Because of the differences between the various measurement systems and procedures, this period has been purposely left unquantified in order to allow the needed flexibility in its application.</p> <p>55) <u>Response</u>: While the Guide allows the use of the Least-Squares Adjustment (LSA) method, many licensees do not employ this method and, consequently, the guide provides guidance on both approaches. Where appropriate, the guide has been revised to remove conflicts between the two methods. The suggested wording has been added.</p>

**RESPONSES TO THE COMMENTS PROVIDED BY THE  
PENNSYLVANIA STATE UNIVERSITY  
A. Haghighat**

Comments	Responses
<p>1) <u>Comment:</u> Because of the axial variation of the BWR void distribution, the source and material distributions require three-dimensional representations. Consequently, it is not evident that the DG-1053 methodology is applicable to BWRs.</p> <p>16) <u>Comment:</u> The verification of the variance reduction method used in the fluence calculation is impractical/impossible.</p>	<p>1) <u>Response:</u> The DG-1053 methodology is applied to a typical BWR in NUREG-6115 and shown to be applicable to BWRs.</p> <p>16) <u>Response:</u> The variance reduction method is an approximation that can have a substantial effect on the calculated fluence. Consequently, this method should be verified to ensure the fluence prediction is reliable. The Guide states that the verification of the variance reduction method should be qualified by comparing the Monte Carlo variance reduction predictions with estimates made without the application of the variance reduction technique. This verification method has been used successfully in the Monte Carlo analyses of NUREG-6115.</p>

**RESPONSES TO THE COMMENTS PROVIDED BY BECHTEL POWER CORP.**  
**William C. Hopkins**

<b>Comments</b>	<b>Responses</b>
2) <u>Comment:</u> The attached figure should be included in the Guide to clarify the dependence of the fluence determination on the fluence uncertainty.	2) <u>Response:</u> The proposed figure provides a significant clarification of the procedure used to determine the fluence and will be included (as Figure-4) in the Guide.

# NUREG/CR-6115 Pressure Vessel Fluence Benchmark Problems

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## ■ Purpose

- Insure accurate fluence predictions and quantify uncertainty
- Standardize vessel fluence methods
- Streamline licensing process

# Application of Benchmark Problems

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- Fluence Methods Provided in DG-1053
- NUREG/CR-6115 Provides Problem Definitions and Reference Solutions
- Licensee Calculates the Benchmark Problems
- Comparisons to the Reference Solutions Provided to NRC
- Fluence Methods Accepted (in part) Based on Agreement with Reference Solutions

# Problem Definition

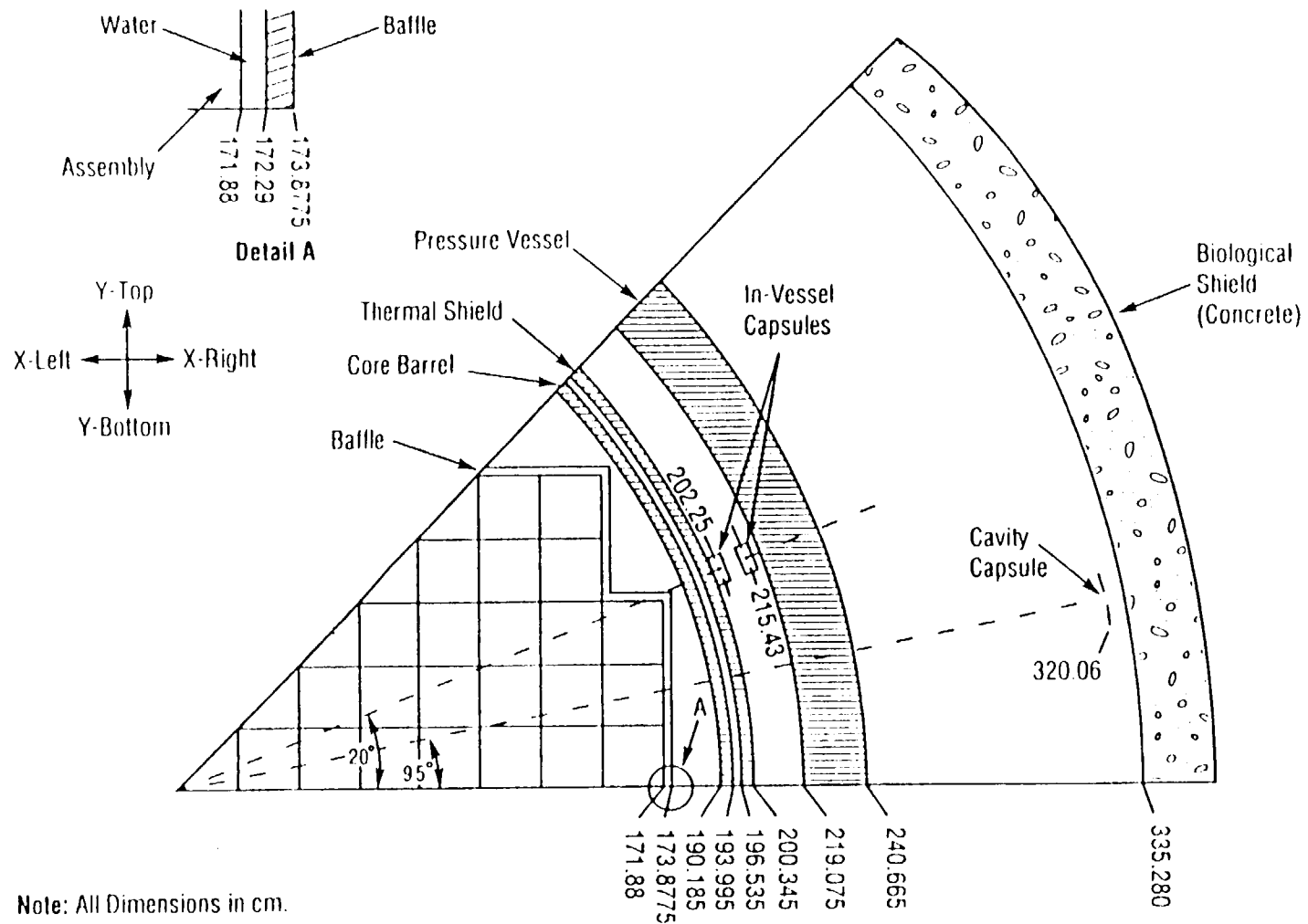
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- Core Types Include
  - PWR - Standard Core, Low-Leakage Core (LL), and Partial Length Shield Assembly (PLSA) Core
  - BWR - Standard Core
- Detailed Description of Problem Materials, Geometry and Pin-Wise Source
- Typical Operating Reactor Geometry and Materials
- Complete Fluence Analysis Involving the Execution of Steps Required for the Determination of  $RT_{PTS}$  Input

# PWR Standard Core Benchmark Problem

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- Geometry
  - Typical core-to-cavity dimensions and materials including a thermal shield and biological shield
- Core Neutron Source
  - Pin-wise power distribution with fuel isotopics vs burnup
- Complete and Detailed Set of Calculation Input Provided
- Dosimeters Located in Standard Wall Capsule and in Cavity
- ENDF/B-VI Dosimeter Cross Sections Provided



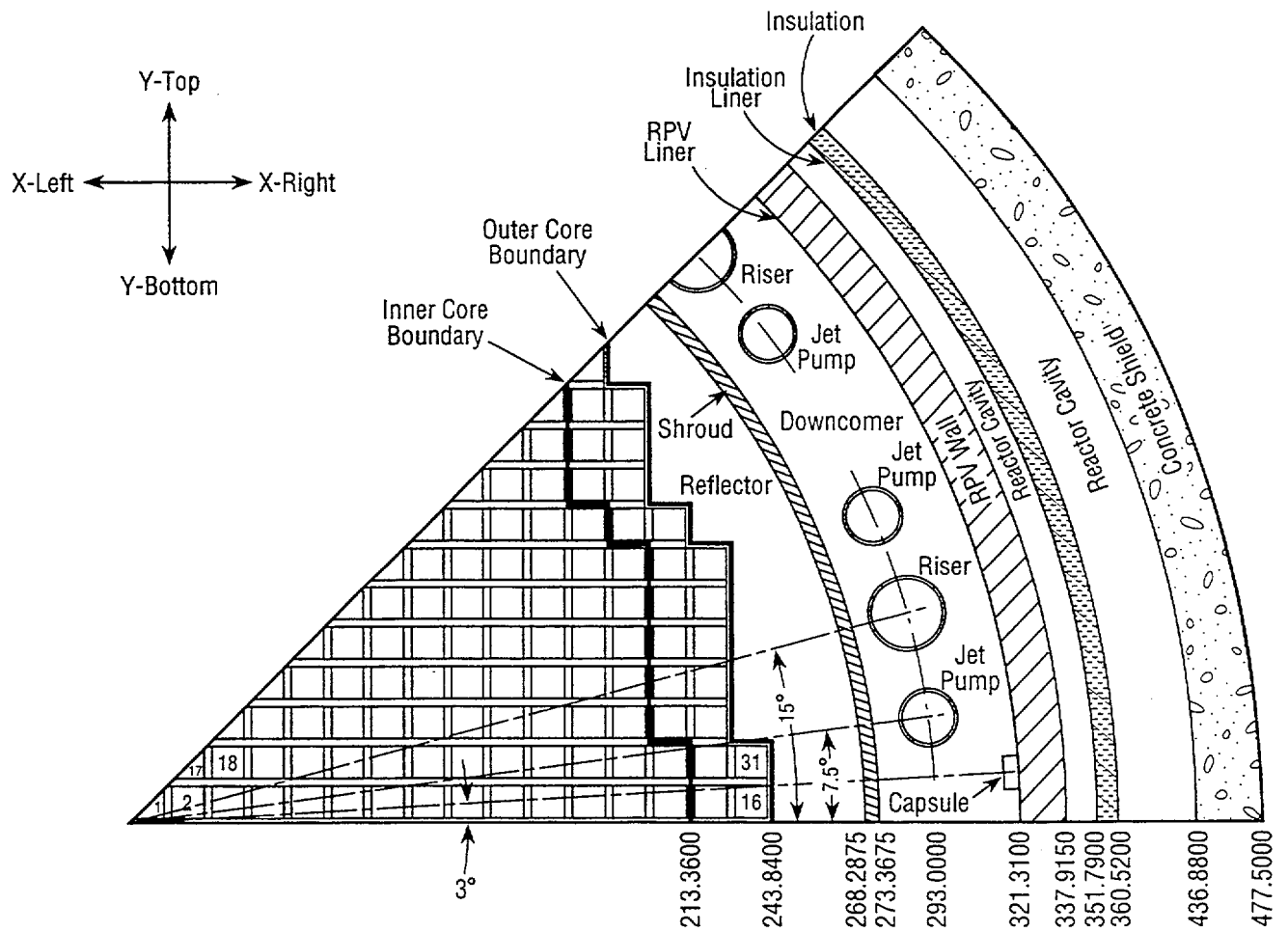
**Location of Surveillance Capsules**

Fig. 2.2.3



Figure 2.2.2.1

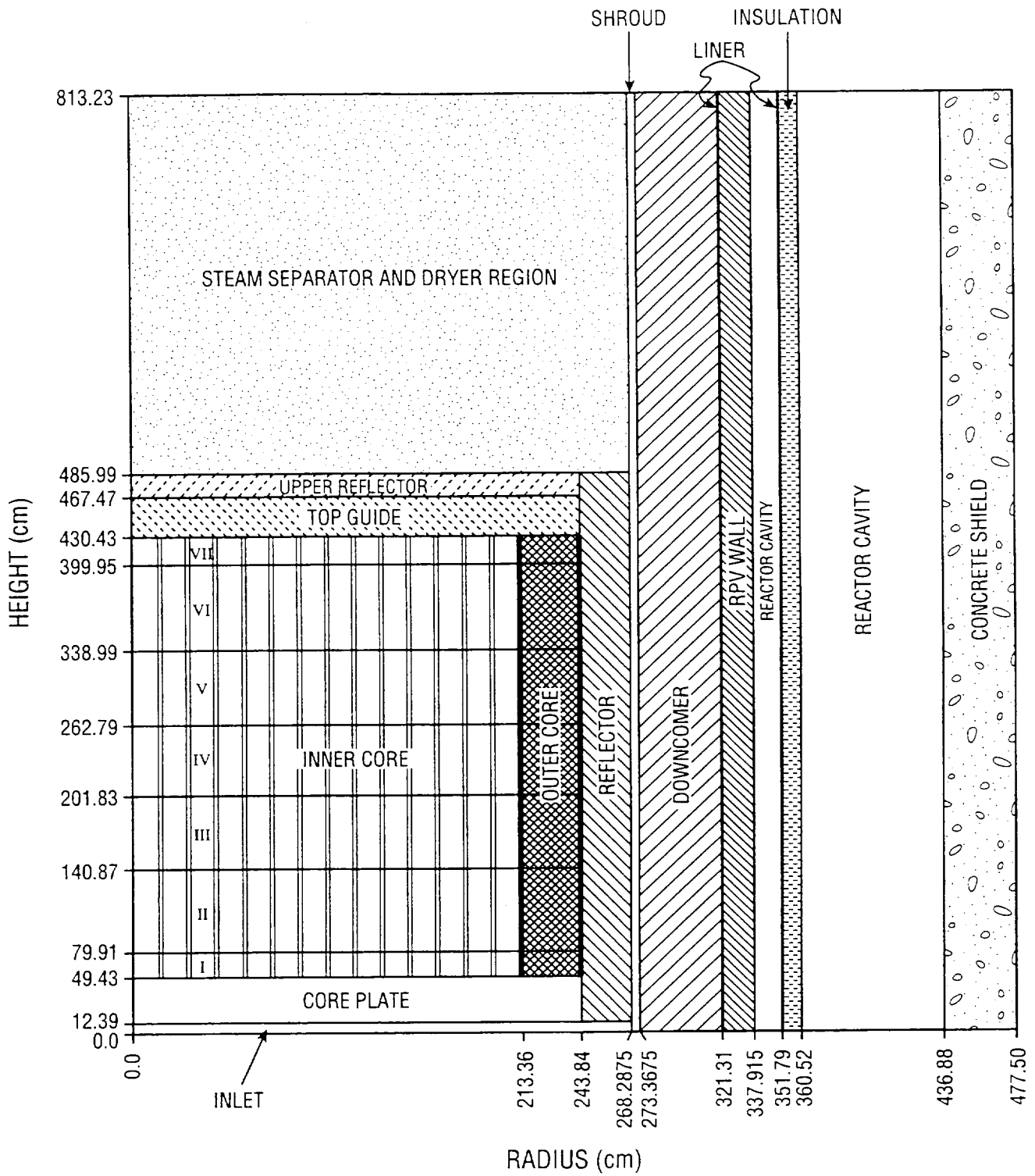
## BWR Planar Geometry



NOTE: All Dimensions in cm

Figure 2.2.2.2

## BWR Axial Geometry



NOTE: All Dimensions in cm

Table 2.2.1

## Standard Core Loading

## Basic Design Data

Reactor		Material
Thermal Power	2527.73 MW (TH)	--
Core Inlet Temp.	536 °F	--
Core Operating Pressure	2010 psia	--
Baffle Thickness	1.5875 cm	SS-304
By-Pass	--	H <sub>2</sub> O (560 °F 2010 psia)
Inner Radius of Core Barrel	190.185 cm	--
Barrel Thickness	3.81 cm	SS-304
Inner Inlet Thickness	2.54 cm	H <sub>2</sub> O (536 °F 2010 psia)
Inner Radius of Thermal Shield	196.535 cm	--
Thermal Shield Thickness	3.81 cm	SS-304
Outer Inlet Thickness	18.095 cm	H <sub>2</sub> O (536 °F 2010 psia)
Inner Radius of Liner Clad	218.440 cm	--
Vessel Liner Clad Thickness	0.635 cm	SS-304
Vessel Thickness	21.59 cm	SA-302B
PV Insulation Air Thickness	1.835 cm	Air
PV Insulation Thickness	10.16 cm	PV Insulation
Cavity Thickness	82.62 cm	Air
Inner Radius of Biological Shield	335.280 cm	--
Bio-Shield Liner Thickness	0.635 cm	SA-302B
Bio-Shield Thickness	213.36 cm	Concrete

Table 2.2.3

## Standard Core Loading

## Design Specification Material Compositions

Mixture	Component	Atom Densities (atom/b*cm)
Core	H	2.82500E-02
	B	2.69200E-05
	O	1.41200E-02
	C	2.58100E-05
	O (fuel)	1.28500E-02
	Al	3.56000E-04
	Cr	1.60800E-05
	Fe	2.20500E-05
	Ni	3.87700E-05
	Zr	5.44800E-03
	U-235	1.12000E-04
	U-238	6.03000E-03
Baffle (SS-304)	Pu-239	2.20000E-05
	Pu-240	7.12000E-06
	Cr	1.85300E-02
	Mn	1.75200E-03
Bypass <sup>+</sup> (560 F)	Fe	5.80700E-02
	Ni	8.57400E-03
	H	4.92900E-02
	O	2.46400E-02
Core Barrel (SS-304)	B	4.90000E-06
	Cr	1.85300E-02
	Mn	1.75200E-03
	Fe	5.80700E-02
Inlet Water Gap (536 F)	Ni	8.57400E-03
	H	5.09600E-02
	O	2.54800E-02
	B	5.10000E-06
Thermal Shield (SS-304)	Cr	1.85300E-02
	Mn	1.75200E-03
	Fe	5.80700E-02
	Ni	8.57400E-03
RPV Liner (SS-304)	Cr	1.85300E-02
	Mn	1.75200E-03
	Fe	5.80700E-02
	Ni	8.57400E-03
Cavity (Air)	N	3.20000E-05
	O	8.00000E-06

+ This composition is also to be used in the water region between the fuel assembly and the core baffle (see Figure 2.2.1).

# Benchmark Problem Solution

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- Tabulated Solution Based on Standard Fluence Analysis Predictions
- Problem Solution Includes
  - Fluence  $> 1$ -MeV,  $> 0.1$  MeV, dpa and spectrum
  - Accelerated and wall capsules and vessel internal and cavity locations
  - Dosimeter reaction rates at capsule and cavity locations
  - Fluence sensitivity calculations

# Benchmark Problem Solution

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- Computational Methods Based on DG-1053
  - DORT  $S_8$   $P_3$  transport
  - $(r, \theta)$  /  $(r, z)$  synthesis
  - BUGLE-93 / ENDF/B-VI cross sections
  - ENDF/B-VI dosimeter cross sections provided
  - ENDF/B-VI fission spectrum

Table 4.2.1

## Standard Core Loading

Flux (E&gt;1.0 MEV) At Pressure Vessel

z	125.488cm	125.488cm	129.186cm	129.186cm	140.282cm
$\theta$	0-T	1/4 T	1/2 T	3/4 T	T
1	3.14799E+10	1.78931E+10	8.69114E+09	4.00968E+09	1.63867E+09
2	3.14939E+10	1.78948E+10	8.69181E+09	4.01204E+09	1.63590E+09
3	3.15515E+10	1.79309E+10	8.71023E+09	4.01916E+09	1.63546E+09
4	3.18090E+10	1.80707E+10	8.77347E+09	4.04608E+09	1.64438E+09
5	3.22184E+10	1.82947E+10	8.87711E+09	4.09152E+09	1.65943E+09
6	3.27523E+10	1.85911E+10	9.01599E+09	4.15139E+09	1.67925E+09
7	3.34669E+10	1.89955E+10	9.20569E+09	4.23439E+09	1.70608E+09
8	3.44603E+10	1.95427E+10	9.45942E+09	4.34323E+09	1.74117E+09
9	3.54574E+10	2.00747E+10	9.70318E+09	4.44796E+09	1.77511E+09
10	3.63728E+10	2.05806E+10	9.93677E+09	4.54712E+09	1.80693E+09
11	3.74744E+10	2.11727E+10	1.02041E+10	4.66105E+09	1.84307E+09
12	3.85964E+10	2.17730E+10	1.04749E+10	4.77398E+09	1.87884E+09
13	3.96873E+10	2.23491E+10	1.07308E+10	4.88026E+09	1.91205E+09
14	4.06848E+10	2.28693E+10	1.09581E+10	4.97269E+09	1.94069E+09
15	4.15408E+10	2.33066E+10	1.11436E+10	5.04551E+09	1.96229E+09
16	4.22000E+10	2.36185E+10	1.12659E+10	5.08990E+09	1.97516E+09
17	4.25965E+10	2.37640E+10	1.13064E+10	5.09949E+09	1.97593E+09
18	4.25805E+10	2.36866E+10	1.12453E+10	5.06928E+09	1.96689E+09
19	4.21634E+10	2.34630E+10	1.11362E+10	5.02312E+09	1.95418E+09
20	4.20061E+10	2.32440E+10	1.10309E+10	4.98065E+09	1.93913E+09
21	4.11917E+10	2.27246E+10	1.08174E+10	4.90050E+09	1.91354E+09
22	4.02185E+10	2.21933E+10	1.06133E+10	4.82491E+09	1.89446E+09
23	3.88038E+10	2.17186E+10	1.04642E+10	4.77406E+09	1.88876E+09
24	3.82263E+10	2.15915E+10	1.04226E+10	4.75869E+09	1.88401E+09
25	3.73962E+10	2.12952E+10	1.03327E+10	4.72600E+09	1.86809E+09
26	3.67420E+10	2.09653E+10	1.02152E+10	4.68137E+09	1.85169E+09
27	3.63552E+10	2.07451E+10	1.01082E+10	4.63723E+09	1.83997E+09
28	3.64033E+10	2.06613E+10	1.00430E+10	4.60702E+09	1.83573E+09
29	3.65714E+10	2.06166E+10	1.00083E+10	4.59093E+09	1.83048E+09
30	3.70498E+10	2.05760E+10	9.92482E+09	4.54562E+09	1.80541E+09
31	3.68078E+10	2.04258E+10	9.81075E+09	4.48443E+09	1.78065E+09
32	3.62594E+10	2.02359E+10	9.70994E+09	4.43473E+09	1.76407E+09

# MCNP Calculations of Benchmark Problems

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- Based on NUREG/CR-6115 Problem Definitions
  - Standard core
  - PLSA core
  - BWR core
  
- Exact Three-Dimensional Geometry
  - Explicit core/baffle/shroud/barrel geometry
  - Pin-wise source description for peripheral assemblies
  
- Multi-Group ENDFB/VI Library Based on BUGLE-93



# MCNP Calculations of Benchmark Problems

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- Region-Wise Importance Weighting
- > 1-MeV Fluence Edit at Selected Vessel Inner-Wall Locations
- DORT/MCNP Differences  $\lesssim 5\%$  Consistent with Methods Uncertainties
  - MCNP statistics
  - DORT geometry
  - DORT numerics
  - DORT synthesis

Fig. 5.3.7

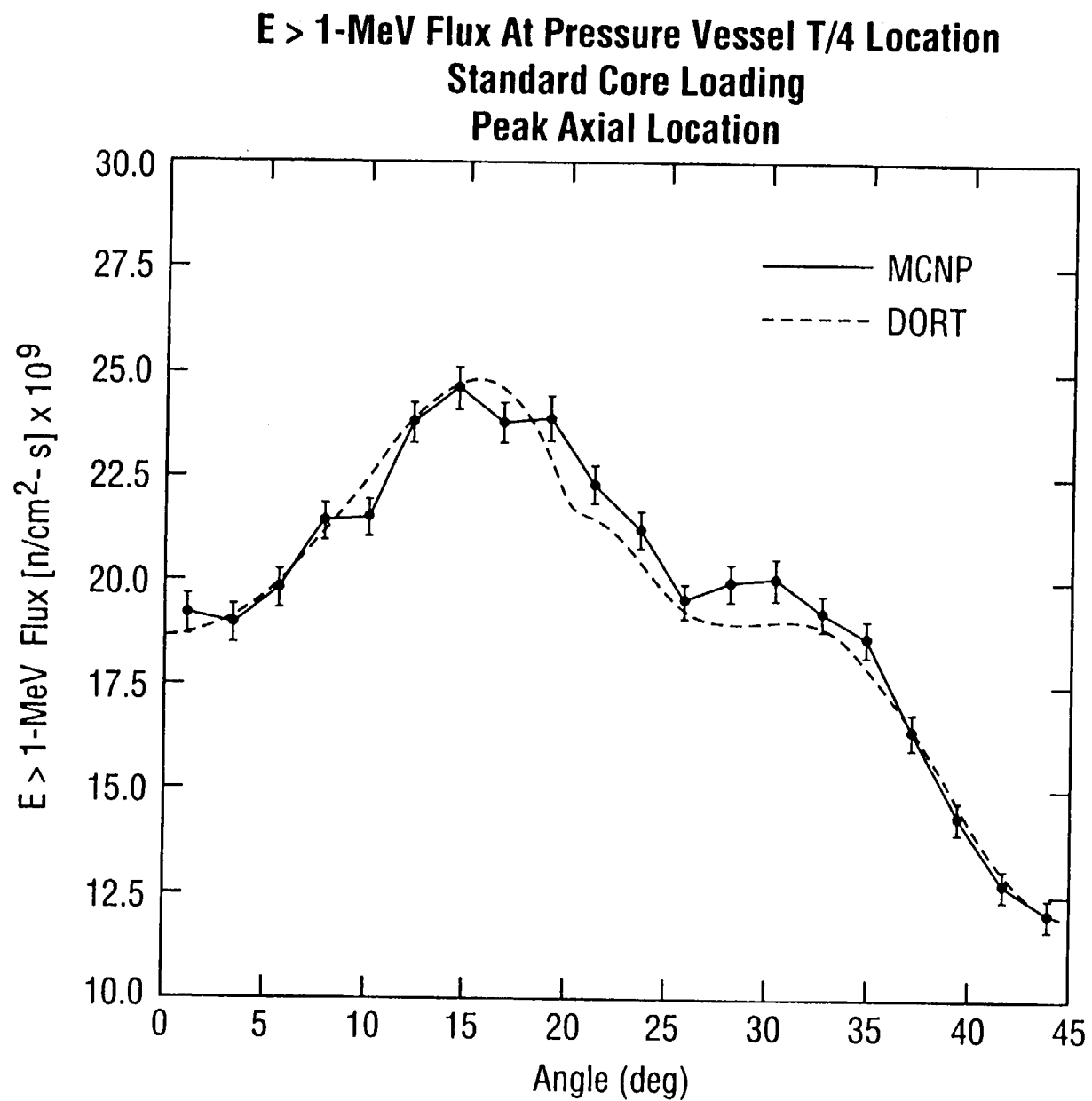


Figure 5.3.9

**E > 1-MeV Flux At Pressure Vessel Lower Weld  
Partial Length Shield Assembly Core Loading**

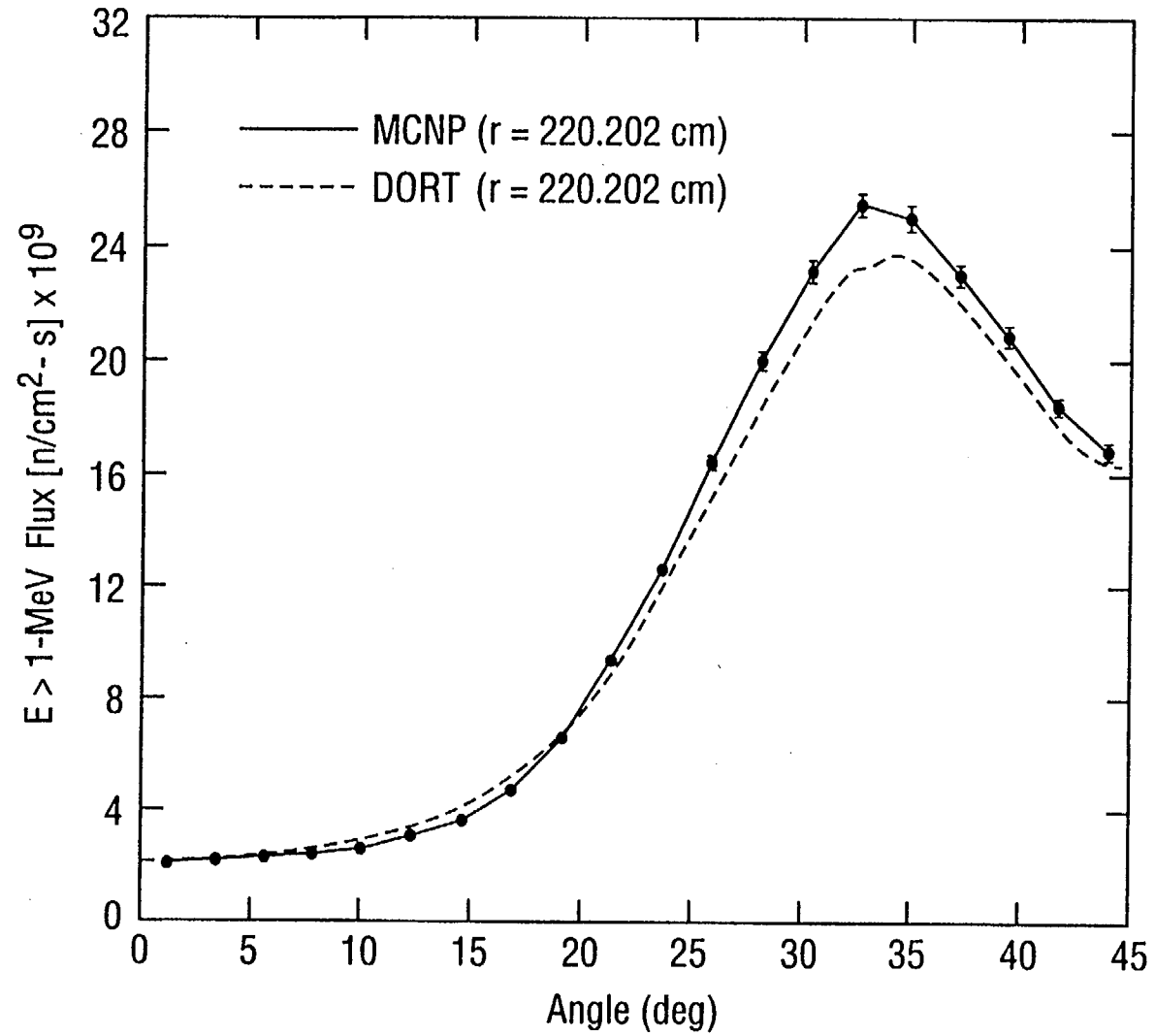


Figure 5.4.5

**Comparison of MCNP and DORT E > 1-MeV Flux In Downcomer  
(r= 278.10 cm) at The Core Axial Midplane**

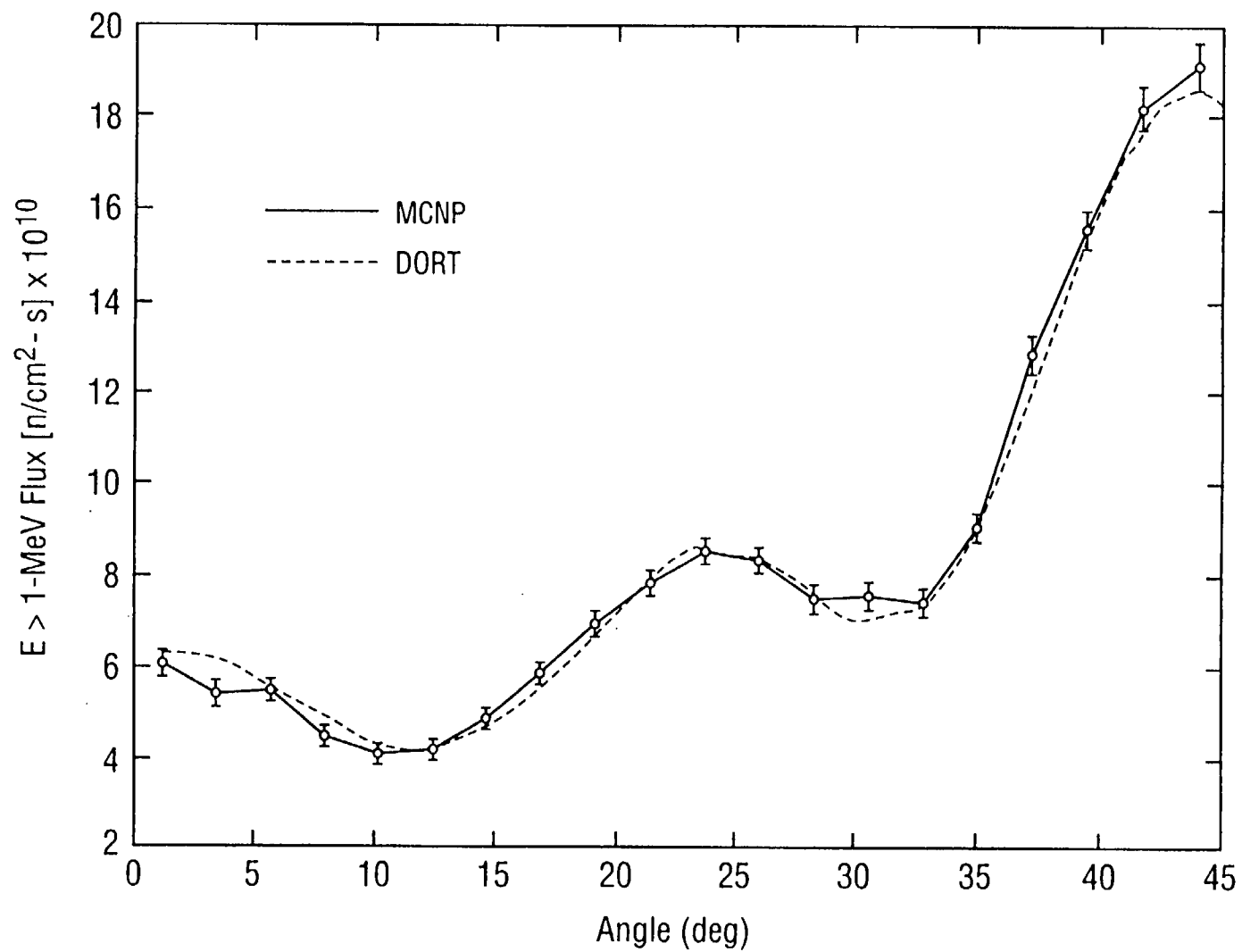


Figure 5.4.7

**$E > 1$ -MeV Flux In Downcomer ( $r = 278.10$  cm) at The Core Axial  
Midplane With Probable Error**

