



**UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS  
WASHINGTON, DC 20555 - 0001**

October 10, 2012

MEMORANDUM TO: ACRS Members

FROM: John Lai, Senior Staff Engineer **/RA/**  
Technical Support Branch  
Advisory Committee on Reactor Safeguards

SUBJECT: CERTIFIED MINUTES OF THE ACRS RELIABILITY AND PRA  
SUBCOMMITTEE MEETING ON NUREG-1934, FIRE  
MODELING APPLICATION GUIDE, ON MARCH 21, 2012

The minutes of the subject meeting were certified on October 3, 2012, as the official record of the proceedings of that meeting. Copies of the certification letter and minutes are attached.

Attachments: As stated

cc H. Gonzalez



Certified on: October 3, 2012  
Certified By: John W. Stetkar

Issued on: October 10, 2012

**ADVISORY COMMITTEE ON REACTOR SAFEGUARDS  
MINUTES OF THE ACRS RELIABILITY AND PRA SUBCOMMITTEE MEETING  
MARCH 21, 2012**

The ACRS Reliability and PRA Subcommittee held a meeting on March 21, 2012 in Room T-2B1, 11545 Rockville Pike, Rockville, Maryland. The meeting convened at 1:00pm and adjourned at 5:24pm. The entire meeting was open to the public. No written comments or requests for time to make oral statements were received from members of the public related to this meeting.

**ATTENDEES**

ACRS Members

John Stetkar, Subcommittee Chairman  
Dennis Bley, Member  
Said Abdel-Khalik, Member  
William Shack, Member  
Steve Schultz, Member

ACRS Staff

John Lai, Designated Federal Official

NRC Staff

Mark Henry Salley, RES/DRA  
David Stroup, RES/DRA  
Gabriel Taylor, RES/DRA  
Tammie Pennywell, RES/DRA  
Naeem Iqbal, NRR/DRA  
Alex Klein, NRR/DRA  
Daneil Frumkin, NRR/DRA  
Ming Li, RES/DRA

Other Attendees

Richard Wachowiak, EPRI  
Francisco Joglar, Hughes Associates  
Susan LeStrange, SAIC  
Richard Peacock, NIST  
Kevin McGrattan, NIST

**SUMMARY**

The purpose of the meeting is to hear staff's discussion of the fire modeling application (analysis) guide, NUREG-1934/EPRI 1023259. The meeting transcripts are attached and contain an accurate description of each matter discussed during the meeting. The

presentation slides and handouts used during the meeting are attached to these transcripts.

Major Issues discussed during the meeting are described in the following Table.

Table 1. Major Issues Discussed During the Meeting

Major Issues Discussed	
Issue	Reference Pages in Transcript
Mark Salley of RES discussed the history of the fire modeling efforts. Rick Wachowiak of EPRI gave the history of the collaborative efforts between NRC and EPRI. The draft report, NUREG-1934, was used for the fire modeling training module in the fire PRA training course sponsored by the NRC and EPRI last year and this year.	9-23
David Stroup of RES stated that the purpose of the report is for the users to apply it as a tool for practical applications of risk-informed performance-base fire protection program for nuclear power plants.	25-28
Member Abdel-Khalik asked how the value of “heat of combustion” for oxygen (in equation 2-10) was derived. Kevin McGrattan of NIST replied that this value is around 12,000-14,000 KJ/kg for all the combustibles and 13,000 KJ/kg is the value used in that equation.	29-32
Member Abdel-Khalik asked what is meant by “the predictive capabilities of the fire models in specific scenarios can extend beyond the range of applicability defined in NUREG-1824”. Kevin replied that some of the correlations are applicable over a much wider range than they examined during the V&V study. The user should provide the justification if they want to use a model outside the range of validation. Member Bley also stated that guidance should be provided in this area.	35-42
Chairman Stetkar asked if the staff has accepted the methods in NUREG-1934 and how the users would address the situation when the scenario is outside of the V&V range. Alex Klein of NRR replied that the staff will independently verify whether or not the licensee's fire models are within the validation range. Staff believes that the fire models are very well-versed in terms of the validation range and the application of these fire models is done in a very conservative manner.	42-53
Chairman Stetkar asked if computer codes such as THIEF and FLASH-CAT are endorsed by the staff even though they have not gone through V&V process. Kevin replied that these are “algorithms” which can be used with any of the fire models in NUREG-1934. Alex stated that if these codes are not V&Ved with the criteria established in NUREG-1824, the staff will ask the licensee to demonstrate that these codes are properly V&Ved. Mark Salley stated that these two algorithms were not developed before publication of NURG-1824, the staff plans to revisit the models in NUREG-1824 in the future.	54-60

Chairman Stetkar stated that only deterministic fire analysis methods are described in Section 1.7 for modeling multiple spurious operations. It did not describe methods for risk-informed applications. Francisco Joglar of Hughes Associates stated that this section should include both methods.	64-66
Chairman Stetkar stated that some of the language in NUREG-1934 could have been clearer. For example, in Section 2.2.1, Step 2, it is not clear whether a best estimate (Mean) value or a 98th percentile value should be used for characterizing the large fire. Alex stated that this topic will be discussed in the July Subcommittee meeting for technical issues facing the NFPA 805 transition.	67-73
Chairman Stetkar asked if the staff has a plan to update NUREG/CR-6738 which was published in September of 2001. Staff will take this into consideration.	74-77
Chairman Stetkar indicated that a few terminologies need to be fixed in the report and equation 2-8 should be corrected.	77-79
Chairman Stetkar and presenters discussed the effects of modeling the incipient stage of fire growth and its implications on the scope of events that are included in the fire database.	82-87
Member Abdel-Khalik and presenters discussed the slope of the T-squared period for fire growth. Rick stated that there are recommended values for fire growth for different fire scenarios.	87-88
Member Abdel-Khalik and presenters discussed fire scenarios 5 and 7 in Chapter 3. Kevin stated that depending on how much detail one needs in the results, the strategy is to apply simple calculations first and then move to more complex models, e.g. from empirical correlations, to zone models, to CFD.	91-100
Francisco stated that sensitivity analysis and referencing other validation studies are two options if the scenario is outside of the validation range.	102-107
Member Bley asked why normal distributions were used for the datasets of the fire models. Kevin replied that most of the datasets are normally distributed except for the few which do not have enough data points.	109-111
Member Bley stated that in Fig 4.1 of the report, the data points are scattered above 300°C. The normal distribution fitting may not be representative in that range. Kevin stated that the goal is to find simplicity for the uncertainty analysis. Member Bley stated that further clarifications may be needed in this area.	112-118
Kevin discussed the plot shown in slide 11 (page 235 of the transcript) and how to alert the reviewer when reviewing the fire models.	119-121
Member Abdel-Khalik asked if all the data points in the plot come from the same test facility. If not, how are the internal biases of the experiments addressed? Kevin and Francisco replied that they assumed the data are unbiased.	122-125

Kevin stated that the material in Table 4-1 of NUREG-1934 addressed the question raised by the ACRS about the “color schemes” shown in Table 3-1 of NUREG-1824.	126-130
Member Abdel-Khalik and presenters discussed the use of the fire models in fire scenarios as described in NUREG-1934.	131-137
Members and staff discussed why uncertainty analysis was not addressed using the CFD model.	137-146
Chairman Stetkar stated that the parameter uncertainties were not addressed in NUREG-1934, whereas they are addressed in NUREG/CR-6850, and one needs to quantify these parameter uncertainties.	146-151
Member Bley made a few suggestions about how to improve the discussions of the three types of uncertainties.	151-153
Chairman Stetkar, Member Bley, and the presenters discussed what is meant by quantifying parameter uncertainty “dependent on the application”.	154-157
Member Schultz stated that the guidance is for the users to follow through and it is the users’ responsibility to get it all done.	157-160
Presenters went through an example to show how to select fire models using the guidelines in NUREG-1934.	161-172
Rick Wachowiak stated that one of the EPRI goals is to look into the fire database to estimate the magnitude of the fire model input parameters (e.g., heat release rate) which causes the fire damage.	177-178
Kevin discussed the steps to evaluate fire-generated conditions and how the sensitivity analysis is performed for important parameters.	178-188
Member Abdel-Khalik asked if it is feasible to develop a multi-zone model for a single compartment. Francisco replied that the zone model is a bridge between hand calculations and CFD.	194-196
Chairman Stetkar summarized the meeting by suggesting that: 1. Providing better guidance when the fire scenario exceeds the V&V bounds.; 2. Providing guidance on how to treat parameter uncertainties for the three categories of models. It is also needed to address the different treatments of MSO (Multiple Spurious Operations) for deterministic and risk-informed applications, respectively.	198

Table 2. Action Items

ACTION ITEMS	
Action Item	Reference Pages in Transcript

None	
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**Documents provided to the Subcommittee**

1. Draft Report, NUREG-1934, "Nuclear Power Plant Fire Modeling Application Guide (NPP FIRE MAG)", February 2012 (ML120470149).
2. Letter to L. Reyes, "Draft Final NUREG-1824, "Verification And Validation of Selected Fire Models for Nuclear Power Plant Applications", ACRS letter, October 26, 2006 (ML062980154).

**Official Transcript of Proceedings**  
**NUCLEAR REGULATORY COMMISSION**

Title:                   Advisory Committee on Reactor Safeguards  
                              Reliability and PRA Subcommittee

Docket Number:     (n/a)

Location:             Rockville, Maryland

Date:                  Wednesday, March 21, 2012

Work Order No.:     NRC-1511

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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

+ + + + +

RELIABILITY AND PRA SUBCOMMITTEE

+ + + + +

WEDNESDAY

MARCH 21, 2012

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ROCKVILLE, MARYLAND

+ + + + +

The Subcommittee met at the Nuclear  
Regulatory Commission, Two White Flint North, Room  
T2B1, 11545 Rockville Pike, at 1:00 p.m., John  
Stetkar, Chairman, presiding.

## SUBCOMMITTEE MEMBERS PRESENT:

JOHN W. STETKAR, Chairman

SAID ABDEL-KHALIK

DENNIS C. BLEY

STEPHEN P. SCHULTZ

WILLIAM J. SHACK

## NRC STAFF PRESENT:

JOHN LAI, Designated Federal Official

MARK SALLEY

DAVE STROUP

ALEX KLEIN

THERON BROWN

## ALSO PRESENT:

RICK WACHOWIAK

FRANCISCO JOGLAR

RICHARD PEACOCK

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1 P-R-O-C-E-E-D-I-N-G-S 1:01 p.m.

2 CHAIR STETKAR: (presiding) The meeting  
3 will now come to order.

4 This is a meeting of the Reliability and  
5 PRA Subcommittee. I am John Stetkar, Chairman of the  
6 Subcommittee meeting.

7 ACRS members in attendance are Stephen  
8 Schultz, Dennis Bley, Said Adel-Khalik, and Bill  
9 Shack.

10 John Lai of the ACRS staff is the  
11 Designated Federal Official for this meeting.

12 The Subcommittee will hear the staff's  
13 discussion of the Nuclear Power Plant Fire Modeling  
14 Application Guide, NUREG-1934/EPRI 1023259. We will  
15 hear presentations from the NRC staff, the National  
16 Institute of Standards and Technology staff, and  
17 industry representatives.

18 There will be a phone bridge line. To  
19 preclude interruption of the meeting, the phone will  
20 be placed in listen-in mode during the presentations  
21 and Committee discussions.

22 We have received no written comments or  
23 requests for time to make oral statements from members  
24 of the public regarding today's meeting. The entire  
25 meeting will be open to public attendance.

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1           The Subcommittee will gather information,  
2           analyze relevant issues and facts, and formulate  
3           proposed positions and actions, as appropriate, for  
4           deliberation by the full Committee.

5           The rules for participation in today's  
6           meeting have been announced as part of the notice of  
7           this meeting previously published in The Federal  
8           Register.

9           A transcript of the meeting is being kept  
10          and will be made available, as stated in The Federal  
11          Register notice. Therefore, we request that  
12          participants in this meeting use the microphones  
13          located throughout the meeting room when addressing  
14          the Subcommittee. The participants should first  
15          identify themselves and speak with sufficient clarity  
16          and volume, so that they may be readily heard.

17          We will now proceed with the meeting.  
18          And, Mark, I guess it is yours.

19          MR. SALLEY: Yes, John, thank you very  
20          much. And, gentlemen, thank you for taking the time.

21          If I could have just two minutes before we  
22          start the formal presentation?

23          CHAIR STETKAR: You can have all the time  
24          that you want.

25          MR. SALLEY: Great.

1 CHAIR STETKAR: We have no lives.

2 (Laughter.)

3 MR. SALLEY: Wonderful.

4 Tomorrow is the 37th anniversary of the  
5 Browns Ferry fire, for what it is worth. And the  
6 reason I bring that up, I got an email this morning  
7 from Mark Miller. Mark, you know, is down in our TTC  
8 in Chattanooga. He sent me some, I guess, unfortunate  
9 news.

10 Jack Lewis passed away Monday. I don't  
11 know if any of you remember Jack. If you had the BWR  
12 series down in Chattanooga, Jack used to teach it. He  
13 retired in 2005 from the NRC. He was here from 1986  
14 to 2005.

15 Jack was a special guy. Just one of the  
16 things that made Jack special was he was an operator  
17 at Browns Ferry during the fire. We were very lucky  
18 two years ago, in 2010, during the 35th anniversary,  
19 if any of you attended it, that Jack came up from  
20 retirement in Chattanooga, and we did a seminar where  
21 Jack told about his experiences and such. And we got  
22 to videotape that.

23 We got a NUREG brochure, BR-0361, that we  
24 put out a few years ago, and this is part of our  
25 knowledge management to capture it. And if you look

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1 at this one, you will find in the video section there  
2 is an interview that Jack did at the TTC with Mark  
3 Miller before he retired. We are in the process of  
4 changing this into a new series called NUREG/KMs, for  
5 knowledge management. We are going to be adding  
6 Jack's seminar that he did two years ago to this and  
7 capture that.

8 So, I just really wanted to take a minute.  
9 Jack, I have known him for a while. To get that  
10 firsthand experience of what happened during the fire  
11 is just priceless. I mean, you can't get that, and we  
12 have got Jack for all time to share with future  
13 generations that will be coming into this.

14 I always liked Jack when he would tell the  
15 real story, and then he would always tell me there is  
16 a story he would tell his grandson about the fire.

17 (Laughter.)

18 And that is when he had the burning cables  
19 in one hand and the fire extinguisher in the other,  
20 and then he was saving northern Alabama.

21 So, Jack, thanks for everything. We will  
22 miss you.

23 Okay. With that, I just wanted to do that  
24 and get on with today. To change gears here, today is  
25 an important day for us. We are going to talk about

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1 a project that we have worked with EPRI for a while.  
2 Rick Wachowiak is, of course, the EPRI side, my  
3 counterpart in EPRI. So, we are going to open this up  
4 and talk to you and get the slides.

5 What we would like to accomplish today is  
6 we would like to discuss this report with the members  
7 of the Subcommittee. We would like to discuss how we  
8 interfaced with our stakeholders in developing this.  
9 We would like to tell you why this report is needed  
10 and the use we see for this going forward into the  
11 future.

12 When we complete this, this is really the  
13 fourth big cornerstone for us in fire modeling, which  
14 I will talk about in a minute. I want to tell that we  
15 are going to start going forward in the area of fire  
16 modeling.

17 And finally, with this project, like we do  
18 with a lot of the innovative first-time projects we  
19 do, we are going to request a letter from you to  
20 endorse this, to publish, and to move on to the next  
21 project.

22 I thought it would be good to start out,  
23 just to give you a very, very abbreviated, short  
24 history of the impact of fire modeling in the U.S.  
25 nuclear power plants. It all goes back to the very

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1 beginning, if you want to get into the very elementary  
2 fire modeling. Back in the sixties and seventies,  
3 when a lot of the plants were still on the drawing  
4 board, one of the concepts we were using back then was  
5 compartmentation. We knew compartmentation was  
6 important for a lot of reasons, fire protection being  
7 one of them.

8 One of the earliest attempts -- and it is  
9 very crude -- at fire modeling was to say, what type  
10 of fire barrier do I need? Do I need a one-hour, a  
11 two-hour, a three-hour fire barrier, firewall,  
12 floor/ceiling assembly, in order to make a compartment  
13 a fire area, as we define it in the regulations?

14 Some of the very early attempts were to  
15 count off the BTUs, divide it by the square footage,  
16 and then try to back that into the standard ASTM E119  
17 curve. That is kind of the roots of where the fire  
18 modeling started and how we used it in the beginning,  
19 in the very beginning.

20 It is also interesting, in 1980, if you  
21 read the Statements of Consideration for Appendix R,  
22 that the rule, as it came out -- and you are very well  
23 aware -- it was very prescriptive. It called out for  
24 one-hour fire barriers with automatic suppression and  
25 detection, and it called out for three-hour rated fire

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1 barriers. Even back when that was being promulgated  
2 and going through the public stakeholder  
3 interventions, you will read some of the comments, and  
4 the industry wanted to go with a design basis fire way  
5 back in the late 1970s and early eighties. Of course,  
6 to get to design basis fire, you need some form of  
7 model to give you that fire.

8 The Commission back then recognized that  
9 there is technology being developed and these things  
10 can be done, but they didn't feel it was mature enough  
11 at the time. So, that really didn't take traction,  
12 other than being acknowledged in the Statements of  
13 Consideration for Appendix R.

14 As we move into the 1980s, UCLA, our own  
15 Nathan Siu and George did a lot of work, and it is  
16 documented in a few NUREG/CRs. And they came up with  
17 COMPBRN. It was where they looked at applying fire  
18 models to different compartments inside the nuclear  
19 power plants.

20 When we first really start seeing it  
21 wholesale across the industry is in 1991 when the  
22 IPEEE comes up, and we are looking for these severe  
23 accident vulnerabilities. One of the things we looked  
24 at was fire.

25 As a matter of fact, this even spawned

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1 EPRI, for example, to develop some new methods. The  
2 FIVE Method was developed. This was its first initial  
3 use. COMPBRN was modified to a COMPBRN E Version.  
4 And we are now starting to see the importance of  
5 putting fire modeling into the PRA and risk analysis.

6 In 2005, we see the SDP come in, where now  
7 we are going to start saying, what is the risk from  
8 these violations and how do I do that? One of the  
9 things with fire is you have to postulate a fire.  
10 Well, how do you postulate a fire? How big is a fire?  
11 How hot is a fire? How long does it burn? Again, you  
12 need tools to do that, and the modeling is where that  
13 comes in.

14 In 2001, we also see NFPA 805 issued. So,  
15 now we see the risk-informed, performance-based  
16 standard. Again, fire modeling plays a big part in  
17 there.

18 In 2004, the NRC amends the regulations to  
19 adopt that. As you well aware, about half the  
20 licensees are in the throes of transitioning to 805.

21 In 2004, we also published NUREG-1805  
22 where we are starting to work with our inspectors to  
23 have them think in terms of fire dynamics, and not  
24 just a rated three-hour barrier looking at a test, but  
25 to look at the hazard and what kind of fire can you

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1 get from that hazard. And we start to introduce fire  
2 dynamics to them in their training methods.

3 In 2007, EPRI and NRC get together. We  
4 understand the importance of having V&V models that we  
5 put together. We did a joint program. It resulted in  
6 seven volumes, a couple of years' worth of work. So,  
7 we now have a V&V for the fire models. We followed  
8 that up in 2008 by performing PIRT, again, to give us  
9 guidance where we want to go with fire modeling.

10 Today we bring in the final big piece, and  
11 that is the Applications Guide. So, we have got  
12 models, five models, that we have worked on. We have  
13 done V&V on them. Now the question is, how does a  
14 user use these in the nuclear power plant environment?  
15 Because there are a lot of unique things that you are  
16 going to see later on in the presentation that you are  
17 well aware of the structures and how we deal with  
18 those.

19 So, this is kind of the thumbnail sketch,  
20 if you will, of fire modeling in our industry.

21 With that, I would like to move to the  
22 next slide and turn it over to Rick.

23 MR. WACHOWIAK: Okay. Thanks.

24 Good morning, for everybody.

25 CHAIR STETKAR: Afternoon.

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1 MR. WACHOWIAK: Or afternoon. Oh, I guess  
2 that's right.

3 (Laughter.)

4 I'm not from around here.

5 (Laughter.)

6 CHAIR STETKAR: You know, the condo in  
7 Hawaii. I'm sorry we had to drag you in.

8 (Laughter.)

9 MR. WACHOWIAK: So, as Mark said,  
10 throughout the history of this, NRC and EPRI have been  
11 working together on various projects associated with  
12 the fire research. We do that under a Memorandum of  
13 Understanding that allows us to share data and  
14 information with research, so that we can provide  
15 useful information to our stakeholders that is  
16 consistent across the board with both industry and  
17 with the regulator.

18 So, that is how we did this project, under  
19 that Memorandum. We put together a team that included  
20 NRC fire modeling experts, industry experts, including  
21 the vendors and the consultants that are actually out  
22 there performing the fire modeling at the plants. We  
23 involved NIST in this. They were involved with a lot  
24 of the testing, fire testing, that we have done that  
25 manifests itself in these examples. And we also went

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1 out to universities and looked for their input from  
2 the research that they have been doing.

3 Go ahead.

4 So, this project itself has had a long  
5 history. Back in 2006, I think there was an ACRS  
6 letter on the verification and validation in which the  
7 recommendation came back to put together a guide for  
8 the users. How do you take this information that we  
9 have now and use it in the power plant environment?

10 We put together our first draft back in  
11 2009 and sent that out for public comments. We got  
12 quite a few public comments on that draft. It was on  
13 the order of hundreds of comments.

14 We needed to address these things to make  
15 sure that the guide we are putting out is actually  
16 going to be useful to the users. A lot of the  
17 comments went toward that. You know, it wasn't seen  
18 as useful to the end-user; I will put it that way.

19 So, we went and took another crack at it.  
20 We added more industry members to the review panel.  
21 We added more NRC experts to the panel and really went  
22 after usability in the guide.

23 When the next draft went out for public  
24 comment, it was a handful of comments, less than 10 I  
25 think is what we ended up with on the second round.

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1 So, we thought that we had accomplished the task that  
2 we went after, but we weren't really done yet in  
3 testing out the document at that point.

4 What we did last year was we incorporated  
5 this document into an Advanced Fire Model Training  
6 Course that we do for fire PRA training. It is one of  
7 the tracks now of our fire PRA training sessions.

8 And we tested the document out in the  
9 training environment with people who were experienced  
10 fire modelers that wanted to become better fire  
11 modelers. As a matter of fact, the first session that  
12 we had, we found a few more issues with the document  
13 in terms of the consistency between the different  
14 examples and the exercise of the empirical  
15 correlations, though the guide initially was focused  
16 more on the computer codes and not so much the  
17 understanding of fire modeling.

18 So, we went back again and said, okay,  
19 let's make sure that when we are using this for  
20 training, people come out of this with an  
21 understanding of how to use the empirical  
22 correlations, what answers they should expect from the  
23 computer codes, how to use the computer codes in  
24 simple applications and in more complex applications.

25 Our second round through with the fire

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1 modeling, experienced people in the second training  
2 course showed there that we did accomplish what we set  
3 out to do and have a document that we believe now is  
4 useful for the people at the plants and is useful in  
5 the training setting for us.

6 MEMBER BLEY: I'm just curious, is the  
7 training just an industry thing or is it a joint --

8 MR. WACHOWIAK: It is a joint training  
9 that the --

10 MEMBER BLEY: It is? Okay.

11 MR. WACHOWIAK: -- that EPRI and the NRC  
12 host. Every other year, we change the sponsorship.  
13 EPRI was the sponsor last year and NRC is the sponsor  
14 of it this year.

15 MR. SALLEY: Yes, I guess the slang you  
16 would hear is 6850 training.

17 MEMBER BLEY: Okay.

18 MR. SALLEY: The 6850 training originally  
19 had three modules. It had the fire PRA. It had the  
20 electrical circuits. And then, there was a fire  
21 analysis piece, which is the basic fire dynamics. We  
22 added a fourth track, which was the HRA piece, Susan  
23 Cooper's and Stuart Lewis' piece. We have now added  
24 a fifth track, and that fifth track is this advanced  
25 fire modeling. So, that training continues to evolve

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1 and develop.

2 And again, that is a joint thing. This  
3 year it is the NRC's turn. There will be two sessions  
4 run, this summer one, and one in the fall in the D.C.  
5 area.

6 MEMBER SHACK: How much is involved in  
7 that training? Several days?

8 MR. SALLEY: Yes, it's kind of cool.  
9 Obviously, all of our training is based off what we  
10 see here at work or what we got from the universities.  
11 So, I guess we kind of follow that. Now we are  
12 putting tracks together. It is a week long. So, it  
13 will be a Monday through Friday, typically.

14 MR. WACHOWIAK: Right. This course  
15 itself, though, is four days, Tuesday afternoon  
16 through Friday afternoon. Is that three days? A  
17 total of -- anyway, so that is the timeframe on that.

18 MEMBER BLEY: And that is the sixth  
19 module?

20 MR. WACHOWIAK: So, this is the fifth  
21 module.

22 MEMBER BLEY: The fifth module.

23 MR. WACHOWIAK: The fifth module.

24 The Monday day for the entire training is  
25 a fundamentals sort of thing, and there is no

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1 fundamentals of advanced fire modeling. That is the  
2 fire modeling course itself.

3 (Laughter.)

4 So, we expect the people to come in, to  
5 know how to use fire models, to have done it before.  
6 In the course itself, we set up the models on their  
7 computer and we actually run, you know, we build  
8 cases. Some of them are the example cases, and we run  
9 cases. We ask to do sensitivities and things like  
10 that. It is a pretty good course.

11 CHAIR STETKAR: Are you still getting  
12 pretty good attendance?

13 MR. WACHOWIAK: We were full both times  
14 last year. And I think the overall 6850 training we  
15 had, I think it was, about 80 people both times last  
16 year.

17 MR. SALLEY: Yes, it is still good,  
18 though. We are getting a lot of foreign involvement.  
19 Typically, we get between 10 and 13 different foreign  
20 nations sending people over. So, it is still a good  
21 thing.

22 One other side note, too. The guys will  
23 get into this in the discussion, but it is fitting  
24 here. The fire modeling, EPRI has been doing that for  
25 years. For about 10 or 12 years, they have a fire

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1 modeling class.

2 I know when I was back in NRR we would  
3 support it with EPRI and do the training. It went  
4 through different permutations, from classrooms, and  
5 then we went to power plants, and we were doing actual  
6 walk-ons. But after a 10-year span, it kind of ran  
7 its course and it needed refreshed.

8 What Rick and I and Ken Canavan discussed  
9 was the 6850 training is still going up and we can  
10 make it better. So, that was the time to evolve that  
11 EPRI training into the joint training and include it  
12 in here. That is kind of the short history of how we  
13 have gone with fire modeling.

14 MEMBER SCHULTZ: Rick, with regard to the  
15 changes that were made to the documentation as a  
16 result of the reviews in the training program, how  
17 extensive were they? I can understand the value of  
18 it, and so forth, but I would like to get a reaction  
19 as to how much changes were made to the documentation  
20 since the draft was reviewed for public comment.

21 MR. WACHOWIAK: Based on the training  
22 course?

23 MEMBER SCHULTZ: That's right.

24 MR. WACHOWIAK: The majority of the  
25 changes that were made there were to discuss how you

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1 use the empirical correlations in concert with the  
2 computer models. I think the document itself, the  
3 examples were very focused on the use of the computer  
4 tools.

5 Because you solve the entire example with  
6 the empirical correlations, we tended to play those  
7 down. But when we went through the first training  
8 class, what we found is, in order for people to  
9 understand how you use the computer models and what  
10 they were getting out of them, they had to have a  
11 basic understanding of the piece parts from the  
12 empirical correlations.

13 So, basically, the changes that were made  
14 were taking the examples that we had and showing how  
15 much of the example you could solve with the empirical  
16 correlations and getting those explained, so that it  
17 would complement the material that we already had.

18 So, it wasn't really a fundamental change.  
19 It was that addition of details, so that you could  
20 understand the computer model examples better.

21 MEMBER SCHULTZ: Thank you. It sounds  
22 like a good change.

23 MR. SALLEY: That was also between the  
24 first and second draft. I guess when we initially  
25 started this, I will take responsibility or blame for

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1 this, as being way too overzealous where I wanted this  
2 to be the end-all, be-all Fire Modeling Applications  
3 Guide. I mean, you always shoot for the moon, right?

4 But after the team had actually worked it,  
5 you really can't write an end-all/be-all from  
6 something where somebody, you know, "This is how you  
7 turn the computer on," "This is how you run a CFD  
8 model and get the output." That is just too big.

9 So, they really needed to reel me in and  
10 reel the scope in, to say, look, the people have to  
11 have some basic understanding of fire modeling. There  
12 is a lot of computer -- you can go online and take  
13 classes from WPI or from the University of Maryland or  
14 Cal Poly. You can go to the Society of Fire  
15 Protection Engineers. But the people have to come  
16 with that basic understanding of how to run a fire  
17 model. Now we will take them to the nuclear  
18 environment. That was, I think, the big change  
19 between the first public comment and the second time  
20 around.

21 CHAIR STETKAR: Good. Thank you, Mark.  
22 I appreciate it.

23 MR. JOGLAR: My name is Francisco Joglar.  
24 I am a member of the Writing Committee for this. I  
25 have a short clarification.

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1                   This training is twice a year. So, after  
2 we revised it, we taught it again with a revised  
3 document, and it did much better. So, we actually  
4 tested it a second time after the revision that we  
5 discussed.

6                   CHAIR STETKAR: Thank you.

7                   MR. WACHOWIAK: Thank you. Good point.

8                   MR. SALLEY: With that, John, I would like  
9 to get into the meat of the presentation and bring the  
10 experts up here.

11                  CHAIR STETKAR: Yes.

12                  MR. WACHOWIAK: Our team that we are going  
13 to have talk to you: Dave Stroup from NRC Research is  
14 going to talk about the upfront material in the  
15 document. And we will bring Francisco up to talk  
16 about the next area where we talk about fire modeling  
17 and implementation. Kevin McGrattan from NIST will  
18 discuss the uncertainty chapter.

19                  And then, our team is going to present the  
20 examples to you after that. They will all be up here  
21 talking about that and be ready to take your  
22 questions.

23                  With that, let's bring up the next group.

24                  Are there any other questions for us?

25                  (No response.)

1 Okay.

2 MR. STROUP: Since there appears to be  
3 some level of interest in how we responded to the  
4 assorted public comments, I will try to bring some of  
5 that into my presentation in a little bit more detail,  
6 at least from my perspective.

7 As Mark said, I am David Stroup. I am the  
8 Senior Fire Protection Engineer in the Office of  
9 Nuclear Regulatory Research.

10 I will be talking about Chapters 1 and 2.  
11 A little bit of it will be redundant to what Mark and  
12 Rick said a couple of minutes ago, but, hopefully, it  
13 will address some of the other questions there.

14 I have been involved in fire protection  
15 for the last 30 years or so, doing fire model  
16 development and application, performance-based design,  
17 and fire testing. I actually started working on the  
18 users' guide about four months before I left my  
19 previous employer, the National Institute of Standards  
20 and Technology. I am hoping I am finally coming to  
21 the end of that task and can move on to something  
22 else.

23 (Laughter.)

24 I have a bachelor's degree in fire  
25 protection engineering and a master's in mechanical

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1 engineering.

2 I will preface what I am going to say with  
3 most of this is my opinion and my perspective as a  
4 practicing fire protection engineer and my four years  
5 of experience working in the nuclear arena.

6 This guide is a landmark as far as fire  
7 modeling is concerned. This guide focuses on the  
8 user. It doesn't address a specific model as such.  
9 The models are just a tool. The user is the one who  
10 is doing the work and trying to come up with the  
11 analysis.

12 And again, it is not a replacement for the  
13 Fire Model Users' Guide or for the -- too many fire  
14 model words. It is not a replacement for the Users'  
15 Guide that comes with a particular model. That guide  
16 tells the user, hopefully, how to put in an input and  
17 how to get an output. It doesn't really tell them  
18 whether that output means anything or not. There  
19 typically is some level of a validation exercise that  
20 the model developer carries out, but that may or may  
21 not be applicable to the particular situation.

22 As I said, this guide is unique in that it  
23 gives a number of practical examples for the user to  
24 follow, similar to you get a piece of software. You  
25 want to run through the examples to make sure it works

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1 on your computer.

2 We have solved eight examples that are  
3 included in the Users' Guide as an appendix. We  
4 identified those nuclear fire protection scenarios, if  
5 you will, over the course of several years. We have  
6 used them several times in various activities.

7 If you are familiar with the fire model  
8 PIRT that we did several years ago, those examples  
9 actually originated out of that exercise, trying to  
10 come up with a sampling that we could give to the  
11 experts to find out where our knowledge was lacking.

12 And as has been mentioned several times  
13 already, we had intended this guide to serve a  
14 training purpose. How do you take fire modeling and  
15 apply it to the nuclear arena?

16 And then, finally, we put a lot of  
17 emphasis on quantifying the uncertainty. There was a  
18 question asked several years ago, when we were working  
19 on putting out the V&V report, that you get an output  
20 from a fire model; how good is that answer? What do  
21 you do with that answer? And hopefully, we have  
22 answered some of those questions.

23 MEMBER ABDEL-KHALIK: I have a question  
24 about process, if you don't mind, John.

25 CHAIR STETKAR: No. I was going to just

1 remind you, you have to flip your own slides here. We  
2 are a low-budget operation.

3 MEMBER ABDEL-KHALIK: You know, just  
4 looking ahead at your slides, there just isn't that  
5 much detail in these slides. So, I assume if you are  
6 going to follow your slides, you are not going to talk  
7 about much, you are not going to talk much about the  
8 details of this report, is that correct?

9 MR. STROUP: I will get into a little bit  
10 more. We will be discussing -- well, Francisco and  
11 Kevin will get into the guts of the details of Chapter  
12 3 and Chapter 4.

13 MEMBER ABDEL-KHALIK: But if we have  
14 questions about Chapters 1 and 2, details, where do we  
15 ask them?

16 MR. STROUP: Yes. Yes, go ahead. Ask  
17 whatever questions you would like.

18 MEMBER ABDEL-KHALIK: Right. Okay.

19 MR. STROUP: Whenever you are ready -- I  
20 should have said that at the beginning, yes, feel free  
21 to ask questions whenever.

22 One of the reasons I took the approach in  
23 preparing this presentation to try to find a balance  
24 between slides that provided some level of  
25 information, but, more importantly, stimulated

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1 questions, because I didn't want to, basically, sit up  
2 here and recite the stuff that was already in the  
3 report.

4 MEMBER ABDEL-KHALIK: Okay.

5 CHAIR STETKAR: Yes, I think we will let  
6 you get through your first three or four slides here,  
7 and then --

8 MEMBER ABDEL-KHALIK: But I have a  
9 question about the estimates of the ranges of  
10 parameters that are given in your table in Chapter 2,  
11 specifically about the equivalence ratio. The  
12 parameter delta H O2, there is sort of a nominal  
13 number that you say doesn't change very much with the  
14 fuels, within 5 percent.

15 But if I take actual data and look at two  
16 extremes, I get widely different values than the  
17 13,100 kilojoules per kilogram value that you have in  
18 there.

19 MR. McGRATTAN: Keep in mind, that is the  
20 heat of combustion based on oxygen consumption.

21 MEMBER ABDEL-KHALIK: Right.

22 MR. McGRATTAN: Now the heat of combustion  
23 based on fuel consumption will range anywhere from  
24 about 10,000 kilojoules per kilogram to about 50,000.

25 MEMBER ABDEL-KHALIK: I fully understand

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1 that.

2 MR. McGRATTAN: Okay, okay.

3 MEMBER ABDEL-KHALIK: So, when you do the  
4 translation --

5 MR. McGRATTAN: Yes.

6 MEMBER ABDEL-KHALIK: -- and you assume  
7 the right stoichiometric, then you do --

8 MR. McGRATTAN: Yes.

9 MEMBER ABDEL-KHALIK: -- the translation,  
10 you get totally different values that are quite a bit  
11 different than the 13,100 kilojoules per kilogram.  
12 So, I didn't quite understand the statement made in  
13 that reference, Drysdale, that this value doesn't  
14 change very much or is within a few percent.

15 Is there a type of fuel for which this  
16 empiricism is --

17 MR. McGRATTAN: That is one of the  
18 beauties of fire. And that is, that number does not  
19 change dramatically. It ranges probably from about  
20 -- I don't know; what would you say? -- maybe 12 to 14  
21 thousand.

22 MEMBER ABDEL-KHALIK: Have you done it for  
23 a solid combustible?

24 MR. McGRATTAN: Yes.

25 MEMBER ABDEL-KHALIK: And have you done it

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1 for coal?

2 MR. McGRATTAN: We have done it for  
3 everything that we have burned --

4 MEMBER ABDEL-KHALIK: And it comes out  
5 within this range?

6 MR. McGRATTAN: -- over the last 40 years.  
7 Yes.

8 MEMBER ABDEL-KHALIK: Well, maybe you  
9 ought to check that again because I get totally  
10 different values when I take the extremes of hydrogen  
11 versus coal.

12 MR. McGRATTAN: If you multiply that  
13 number by the stoichiometric ratio --

14 MEMBER ABDEL-KHALIK: Yes, I have done  
15 that.

16 MR. McGRATTAN: -- the heats of combustion  
17 are fairly close. I mean, that is a very well-known  
18 concept in fire protection engineering.

19 MEMBER ABDEL-KHALIK: I mean, close is  
20 probably a relative term.

21 MR. McGRATTAN: Right.

22 MEMBER ABDEL-KHALIK: Okay.

23 MR. McGRATTAN: Yes. So, keep in mind  
24 that, when we discuss fires in nuclear power plants,  
25 we are typically burning cable jackets, insulation,

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1 you name it, for which the heats of combustion are not  
2 very well-known. In fire, we take that 13,000 number  
3 when we don't have more specific data. So, that would  
4 be fairly robust in describing a wide variety of  
5 fuels.

6 MEMBER ABDEL-KHALIK: Well, you know, the  
7 variability I am talking about is within 50 percent of  
8 that number. So, if you say that we don't know the  
9 heat of combustion within that range, then I can  
10 understand why you would fall to that.

11 MR. McGRATTAN: I would argue it is  
12 closer, it is tighter than 50 percent, but 10 or 20  
13 percent I think would be a reasonable estimate.

14 MEMBER ABDEL-KHALIK: So, the range of  
15 values that are given in this table are based on this  
16 constant value of delta H oxygen?

17 MR. McGRATTAN: Yes, yes.

18 MEMBER ABDEL-KHALIK: Okay. Thank you,  
19 John.

20 MR. PEACOCK: I am Rick --

21 CHAIR STETKAR: You're on.

22 MR. PEACOCK: I am Rick Peacock from NIST.

23 Most of that comes from a peer review  
24 journal article. It is largely a wide range of  
25 hydrocarbon fuels. That journal article certainly

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1 didn't get the hydrogen --

2 MEMBER ABDEL-KHALIK: Right.

3 MR. PEACOCK: -- but a very wide range of  
4 typical fuels it does.

5 So, I think the answer is everybody is  
6 right.

7 (Laughter.)

8 MEMBER ABDEL-KHALIK: Well, that is why I  
9 looked at the extremes.

10 MR. PEACOCK: Right.

11 MEMBER ABDEL-KHALIK: I looked at hydrogen  
12 and I looked at coal, and they were definitely far  
13 away from the value that is used there.

14 MR. PEACOCK: Yes, it is a very tight  
15 range. For the typical fuels you see in fires, it is  
16 not all-inclusive certainly.

17 MEMBER ABDEL-KHALIK: Okay.

18 CHAIR STETKAR: Dave, go on.

19 MR. STROUP: Yes, one reason why I  
20 attempted to defer to Kevin to address those  
21 parameters in detail, even though they are covered to  
22 some extent in Chapter 2, I wanted Kevin to have the  
23 opportunity to discuss those because they fit better  
24 into his expansion of the quantitative estimates of  
25 uncertainty that we include.

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1           Just briefly revisiting the whole training  
2           issue and function of the guide, we did have several  
3           professors providing either direct or peripheral  
4           support in looking at this guide to help us improve  
5           the language. And while we couldn't achieve Mark's  
6           objective of making it a real textbook, we benefitted  
7           from their input in helping to move it in that  
8           direction.

9           We have Professor Jim Milke from the  
10          University of Maryland and Professor Fred Mowrer, who  
11          was formerly at the University of Maryland, is now at  
12          Cal Poly, working with the writing team, as well as is  
13          Mark.

14          Mark may have mentioned this earlier, but  
15          one of the peer reviews that we did was we sent the  
16          report to Jose Torero at the University of Edinburgh,  
17          who took his students and went through a number of the  
18          examples.

19          We have discussed the impact of NFPA 805  
20          before, but the critical piece of NFPA 805 was it was  
21          one of the first times where they really spelled out  
22          the need to do some type of verification and  
23          validation of fire models.

24          When NRC adopted 805 in the regulations,  
25          it was then necessary to try to figure out what that

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1 verification and validation really meant. It was only  
2 the words and the requirement were in 805; it really  
3 didn't give you any guidance as to how to go about  
4 doing that.

5 So, out of that came NUREG-1824, which  
6 provided a lot of data and analysis of the models and,  
7 ultimately, ended up with a set of colors for the  
8 various models. I don't know how many people remember  
9 the color charts, and Kevin will get into that a  
10 little bit more later.

11 And I spent the last couple of weeks  
12 rereading the transcripts from a lot of the meetings  
13 when we went to the ACRS to talk about 1824. And  
14 their concern, and I think I share that concern, is  
15 there was a lot of information there, but it really  
16 wasn't any guidance to the user as to what to do with  
17 it all. This Users' Guide now provides that guidance.

18 And specifically, during our presentations  
19 to the ACRS at the time, we promised them that we  
20 would do this Users' Guide. When they sent the letter  
21 supporting publication of the Users' Guide, they had  
22 a couple of requirements, which I think we have done  
23 a pretty good at this stage of addressing. And that  
24 is estimating ranges or parameters over which the fire  
25 models are applicable and, also, taking that big step,

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1 as I see it, towards providing quantitative estimates  
2 of the uncertainty.

3 MEMBER ABDEL-KHALIK: Okay. So, you have  
4 provided estimates of the non-dimensional parameters  
5 with which the models had been verified and validated,  
6 and that's great. But, then, you go ahead and make a  
7 statement that says, "It is the consensus opinion of  
8 the authors of this guide that the predictive  
9 capabilities of the fire models in specific scenarios  
10 can extend beyond the range of applicability defined  
11 in NUREG-1824."

12 This is a very dangerous statement to put  
13 in a document that you are going to give to a user.

14 MR. JOGLAR: Well, we can certainly  
15 discuss that issue in terms of what to write, but the  
16 reality applied in this guide is that, when applying  
17 fire modeling, we will find scenarios that are outside  
18 those bounds. Although we probably will need to  
19 address the comment you are bringing up in terms of,  
20 yes, what language to use to express that, we have a  
21 section in there that provides guidance of what to do  
22 if you have to analyze a case where some of the values  
23 are outside that range.

24 That range, it is based on the V&V that we  
25 have, that it is certainly a limited set of

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1 experiments. "Limited" is a relative term. And  
2 future work, as you will hear, involves expanding that  
3 to realize those ranges.

4 MEMBER ABDEL-KHALIK: Yes, but physics is  
5 not sort of a consensus-type subject. You don't sort  
6 of say okay, unless you have some evidence that that  
7 is the case. How did this group reach that consensus?

8 MEMBER BLEY: They tell later on,  
9 actually.

10 MR. McGRATTAN: I will address part of it.  
11 Some of these empirical correlations that were part of  
12 the V&V, well, that are included in the models, when  
13 you look at the development of these correlations,  
14 they are applicable over a much wider range than we  
15 examined during the V&V study. And I think that is  
16 all that this statement says. It says 1824 is  
17 limited.

18 And 1824 was a great effort and good  
19 start, and we would like to continue to increase the  
20 database of validation, but we only looked at 26  
21 experiments. There were only six different  
22 experimental series, so six experimental  
23 configurations, 26 experiments in all. So, there is  
24 a lot of fire phenomena that lives outside of the  
25 parameter space that we verified and validated these

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1 models in.

2 And we don't want to limit the user. So,  
3 if the user is using a model and the scenario that he  
4 or she wants to study falls outside of our validation  
5 space, we don't want to say to the user, "You can't do  
6 it." We're saying to the user, "You have to provide  
7 evidence of your own outside of 1824 that this model  
8 is appropriate."

9 So, we are putting it back on the user to  
10 say, "You have to justify use of this model. If you  
11 can't use 1824, you have to develop your own  
12 criteria."

13 MEMBER ABDEL-KHALIK: I fully understand  
14 that a specific phenomenon within a model may have  
15 already been validated and verified within a wider  
16 range than the collective model.

17 MR. McGRATTAN: Right.

18 MEMBER ABDEL-KHALIK: But, nevertheless,  
19 what we are talking about is the application of the  
20 entire model. And therefore, the fact that some  
21 pieces of it were empirically validated over a wider  
22 range does not mean that the entire model is valid  
23 over that wider range.

24 MR. JOGLAR: Our V&V study, it doesn't  
25 validate a model; it validates capabilities of the

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1 model. And some of the correlations that are included  
2 in those models are also evaluated separately,  
3 independently.

4 So, although I personally agree with your  
5 concern in terms of that statement, we, as a team,  
6 have the same concern. I mean, we know of  
7 applications of this that may be outside that limited  
8 range, and we took it as a challenge to start  
9 addressing that problem in this guide, although we  
10 know that more V&V is necessary and more guidance will  
11 eventually be necessary.

12 MR. McGRATTAN: Right. In fact, of the  
13 eight scenarios that we describe in the appendix, not  
14 a single one of them fell completely within our  
15 validation space. For each one, we had to say why we  
16 could use this model outside of that space.

17 MEMBER BLEY: I am thinking maybe I  
18 misunderstood something you said earlier. But I was  
19 coming at this from a different direction, and I will  
20 later, when we get to the uncertainty discussion.

21 But I thought it was essential that you  
22 warn people that they may get cases to analyze for  
23 which the model has not been validated. And the  
24 impression I had was that probably happens a lot. You  
25 are just confirming that a bit.

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1 I felt that the advice provided for those  
2 cases where you weren't completely within the  
3 validation space was pretty sketchy, it seems to me.  
4 And there are things in 1824 that would help people,  
5 but you give them hints. But I think in those cases  
6 the hints are really hints; they aren't anything  
7 approaching the guidance I think eventually they will  
8 need.

9 So, that was the one area where I was kind  
10 of worried about all this.

11 MR. JOGLAR: We share that concern. A  
12 part of that answer is that this is -- the V&V is kind  
13 of a state-of-the-art document. When we tried to test  
14 all of this, we recognized these problems. This  
15 overall topic is kind of new. We are trying to  
16 advance it because --

17 MEMBER BLEY: Well, at least you have  
18 raised the flag.

19 MR. JOGLAR: Yes. For example, in NFPA  
20 805, it says models have to be verified and validated.  
21 Well, a couple of years ago, three or four years ago,  
22 you would open a fire model users' guide; there was  
23 not a stamp that these were verified and validated.  
24 So, that step was taken in order to make this  
25 provision of the code, of NFPA 805, usable.

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1                   Now that we are there, we are finding new  
2 challenges to make it happen. And all of them,  
3 because of the requirements of testing --

4                   MEMBER BLEY: Are you getting much  
5 feedback from the people not just at your classes, but  
6 who are trying to apply this, coming back with  
7 questions? I don't even know how that process worked.

8                   MR. STROUP: Yes, we get a lot of  
9 questions in a number of areas related to the V&V.  
10 Now our V&V is really the first time anybody has tried  
11 to put a number, if you will, on the uncertainty from  
12 a fire model.

13                   In the past, the entire fire protection  
14 industry would take the output from a fire model and  
15 say, well, that's the answer. They may run two or  
16 three cases, but the assumption was that the model was  
17 giving you the right answer.

18                   Even the model developers would typically  
19 look at things from a much more subjective,  
20 qualitative standpoint and say, "Their model has good  
21 agreement. It provides reasonable approaches," and  
22 other types of unqualified kinds of words.

23                   But, right now, we have been getting  
24 questions as far as, you know, the big one, "What do  
25 I do if it is outside the validation range?" And

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1 also, "Well, you validated FDS Version 3. I'm using  
2 Version 5. When is NRC going to approve the latest  
3 version?"

4 Well, my friends in NRR and I debate this  
5 question back and forth. We really don't necessarily  
6 approve the model. A use of the model may be  
7 approved, but we really don't approve the model.

8 And one thing that comes out of all that  
9 discussion is that probably the Users' Guide, and very  
10 definitely 1824, need to become a living document.  
11 Kevin and his colleagues at NIST have been keeping  
12 CFAST and FDS up-to-date and rerunning the existing  
13 V&V and adding more data suites. We at NRC hope to  
14 tap into those resources and do the same for the other  
15 models that have been verified and validated and  
16 expand that range, that validation range, which, as  
17 Kevin said, is not necessarily the range of  
18 applicability of the models or some of the individual  
19 correlations.

20 MR. JOGLAR: From the application side --  
21 and this is my own experience -- now when you use  
22 these models, you need in your documentation to argue  
23 why it is good. To the extent that you are within the  
24 bounds of this V&V, that gives you a good argument for  
25 that. To the extent that you fall outside, you have

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1 to come up with those justifications, which is a step  
2 in the right direction in terms of -- so, yes, from  
3 the applications, yes, it involves now a justification  
4 of why this calcs are good.

5 CHAIR STETKAR: Let me ask the same  
6 question from a little different tact. This is a  
7 Users' Guide. We have heard that this is targeted  
8 against the people in the trenches doing real fire  
9 analysis to solve real problems today.

10 There are -- I have forgotten the count --  
11 47, or something like that, nuclear power plants out  
12 there with real people in the real trenches doing real  
13 fire analysis to solve real problems today; namely,  
14 the transition to NFPA 805.

15 The NRR staff -- and I am going to bring  
16 NRR into this -- is reviewing those. The NRR staff  
17 reviews those against review criteria, and the review  
18 criteria they review against is NFPA 805 that says the  
19 models shall be verified and validated.

20 Now, given the fact that most of the real  
21 fire scenarios that the people in the trenches are  
22 actually struggling with today are outside of the  
23 validation range of the models that they are being  
24 told to use, does NRR formally accept the methods in  
25 NUREG-1934 as justification to support the analyses

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1 that people are doing today? And if so, where is that  
2 documented, so that the people doing the analyses know  
3 what sort of guidance to use?

4 I saw you Alex. I knew you were there.

5 (Laughter.)

6 MR. KLEIN: I appreciate the opportunity  
7 to speak to you.

8 CHAIR STETKAR: I'm sure you do.

9 Identify yourself.

10 MR. KLEIN: My name is Alex Klein. I am  
11 the Branch Chief in NRR, Fire Protection.

12 In terms of what NRR does to determine  
13 acceptability of fire models and the application of a  
14 particular fire model by a licensee, we certainly look  
15 at what the requirements say in NFPA 805. We look at  
16 what our guidance is. And we look at specific  
17 applications of the fire models when we go on our  
18 audits. We ask for the specific input files. And we  
19 will independently verify whether or not we believe  
20 that the licensee's use of the fire models are within  
21 the validation range. And then, we will make that  
22 assessment.

23 And we will ask that licensee, if we  
24 believe that licensee is not providing us with enough  
25 basis or documentation as to why they believe the

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1 application of that model outside of that validation  
2 range is acceptable, we will go back to that licensee,  
3 and we have been.

4 If you have had an opportunity to look at  
5 the RAIs, the Requests for Additional Information,  
6 that we have asked licensees -- and, John, we will  
7 come to you --

8 CHAIR STETKAR: We will be involved in  
9 that soon, yes.

10 MR. KLEIN: -- here in the next few  
11 months. We will provide you with a lot more detailed  
12 information.

13 But I believe that our fire models, both  
14 in NRR and the contractors that we are using, are very  
15 well-versed in terms of the validation range of these  
16 fire models. So, I've got confidence in terms of  
17 NRR's ability to make the judgment as to whether or  
18 not the applicability.

19 Now, having said that, what I am also  
20 seeing, at least the input I am receiving from our  
21 consultants and our contractors on review of these  
22 fire models, is that the application of these fire  
23 models is done in a very conservative manner. So,  
24 there's margin there.

25 So, you know, in terms of validity, you

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1 have to balance that against margin. So, all of that  
2 is taken into account in our ultimate determination.  
3 We are not done yet. We are just beginning to look at  
4 their models.

5 CHAIR STETKAR: The reason I raised the  
6 question is partly what you just said. I have heard  
7 various people complain that the fire models are  
8 conservative. And I have heard people saying, well,  
9 to keep the results and the application within the V&V  
10 bounds of a particular fire model, they have had to  
11 adjust some of their input parameters to very  
12 conservative values, so that, indeed, they fit the  
13 narrow ranges, which gives them conservative results,  
14 and so forth.

15 I guess I am looking for kind of coherent  
16 guidance about what -- you know, just so it isn't on  
17 an ad hoc 49 times that NRR has to go out necessarily  
18 and plant-by-plant, application-by-application justify  
19 something. You have provided some bases here. I kind  
20 of agree with Dennis that the guidance on what you  
21 kind of ought to do isn't very detailed. But it is an  
22 area where people I think are struggling.

23 It would seem that it should get a little  
24 more attention, both in this document, but without  
25 research kind of running off in one direction without

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1 close interaction with NRR, who is then going to come  
2 back and bring people and say, "Well, we have no  
3 justification."

4 MR. JOGLAR: From the application side,  
5 because we are struggling with this question, and  
6 because the fire modeling is done for the most part in  
7 support of fire PRAs, analysts take the approach that  
8 is taken in the PRA, that you start conservative and  
9 go refining on an as-needed basis. And that is why  
10 you see some of the conservative comments that you are  
11 mentioning, that, okay, let me reduce the size of the  
12 room because I know it is going to be conservative.  
13 If that proved to be okay for us, we are going to use  
14 that argument to say we don't have this type of  
15 scenario.

16 And to the extent that this argument can  
17 be used, the people are using it because it is part of  
18 the fire PRA, in the way we do fire PRA, which is  
19 start conservative and refine when necessary.

20 MEMBER ABDEL-KHALIK: Well, let me just  
21 point to a specific case where this may be a problem,  
22 the case of underventilated compartment fires, and  
23 none of the V&V calculations really cover that range.  
24 And the argument is made in the text that, if they  
25 were to assume it to be well-ventilated, that that

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1 would be a conservative assumption, but that may not  
2 be reality.

3 How prevalent is this condition? And how  
4 often do people have to make that assumption?

5 MR. JOGLAR: My opinion on this is that  
6 the results you would get evaluating underventilated  
7 conditions would be, from an industry perspective,  
8 heavily questioned by the regulators because, how can  
9 you assure it is going to remain underventilated  
10 throughout the scenario?

11 So, in my opinion, those cases, you  
12 evaluate them, but you base your conclusions assuming  
13 that this fire can go on because, when the fire  
14 brigade is going to open the door and supply  
15 ventilation, there are many, many different cases that  
16 can happen in a room to provide ventilation. So, all  
17 of them must be evaluated.

18 But, yes, in the power plants most of the  
19 rooms are closed.

20 MEMBER ABDEL-KHALIK: I mean, I am just  
21 trying to wrap my arms around the argument that you  
22 made. You are essentially saying that the assumed  
23 scenario is nonsensical?

24 MR. JOGLAR: Which scenario specifically?

25 MEMBER ABDEL-KHALIK: The assumed

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1 underventilated scenario, because there is no such  
2 thing as an underventilated scenario.

3 MR. JOGLAR: Well, there are procedures  
4 that govern the response of fire brigades to rooms,  
5 and they will open doors, vent smoke out. And to just  
6 run a case that you assume this room is going to  
7 remain closed and, therefore, has ventilation issues  
8 over the course of the full scenario, I believe it is  
9 less likely than the case where people will open doors  
10 and try to suppress the fire.

11 MEMBER ABDEL-KHALIK: It is always a  
12 matter of time, right? I mean, if the fire had  
13 already extinguished before the people opened the  
14 door, then you are getting a totally unrealistic  
15 answer.

16 MR. JOGLAR: If the fire already  
17 extinguished, that suggests a relatively long fire,  
18 right, that has generated some damage.

19 MEMBER ABDEL-KHALIK: No. Because it is  
20 the other problem.

21 MR. JOGLAR: More fire --

22 MEMBER ABDEL-KHALIK: The fire has already  
23 extinguished. So, it doesn't matter when people open  
24 the door. There is no fire in that compartment  
25 anymore.

1 MR. JOGLAR: But it is a matter of how  
2 much damage is generated. If it doesn't generate much  
3 damage, it is not really significant.

4 MEMBER ABDEL-KHALIK: But it might  
5 generate a lot more damage if it was assumed to be  
6 ventilated throughout.

7 MR. JOGLAR: If you are doing this  
8 analysis like most of it is done in support of risk  
9 assessments, those risk assessments involve the  
10 evaluation of impacts of just one component, two  
11 components, and many things failing. So, the  
12 contribution of risk associated with fires that are  
13 very small or propagated are accounted for. It is  
14 just a matter of you are modeling it or not.

15 MEMBER ABDEL-KHALIK: I guess I don't want  
16 to really carry this too much further. The point has  
17 been made that somehow the justification for using the  
18 models beyond the validated range sort of perhaps  
19 needs to be strengthened, and that the generic  
20 statement that we think it is okay or it is the  
21 consensus opinion that you can go ahead and use the  
22 models beyond --

23 MR. McGRATTAN: I don't think that is what  
24 it says at all. I think we are putting the onus on  
25 the user of the model to justify why they are using it

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1 in the way they are. I don't think it is carte  
2 blanche to do whatever you want.

3 CHAIR STETKAR: The statement, for the  
4 record, "It is the consensus opinion of the authors of  
5 this guide that the predictive capabilities of the  
6 fire models in specific scenarios can extend beyond  
7 the range of applicability defined in NUREG-1824/EPRI  
8 1011999. Regardless, additional analysis is required  
9 to address situations where some of the analysis  
10 parameters fall outside of the range of applicability,  
11 defined in NUREG-1824/EPRI 1011999."

12 So, it says you think they can be  
13 extended, but it says you kind of have to do analysis  
14 to do this --

15 MR. JOGLAR: The burden is on the user,  
16 not on 1824, to show that these are --

17 MR. McGRATTAN: And I will add something  
18 that is funny. One of the reasons why it took so long  
19 to develop this guide, and why it went through public  
20 comment twice, is that we, ourselves, when we became  
21 the users and worked these eight examples, the  
22 reviewers a number of times said, "Well, wait a  
23 second. How can you" -- and we said, yes, we can. We  
24 didn't follow our own advice a number of times, and we  
25 found, when we had to justify why we were using a

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1 particular model outside of its range, sometimes we  
2 had to throw those analyses out because we couldn't  
3 ourselves do it.

4 So, that is what took us a lot of time.  
5 We know now what a user is going to face.

6 MEMBER BLEY: Well, you bring up an  
7 interesting point. You could throw an analysis out  
8 because you wouldn't use it as an example, but some  
9 poor guy in the plant has got to do something with it.  
10 He has got to find a way around that. And that is  
11 where I thought we need more help for him.

12 MR. McGRATTAN: Maybe fire modeling may  
13 not be the answer. I mean, you may have a situation  
14 for which you can't use a fire model and you have to  
15 just use some upper bounds, some bounding analysis.  
16 That's life. That is the way it --

17 MEMBER BLEY: I am going to return to this  
18 later, when we get to the uncertainty analysis because  
19 there are some things that might turn up there.

20 I know we are a little bit late, but I  
21 wanted to follow up just with a question for myself,  
22 and it would be more an industry question. When I  
23 first got involved with commercial plants, I was kind  
24 of surprised they weren't rigged like surface ships in  
25 the Navy that I had seen. There, if you had a fire,

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1 you kill the inlet fans and you put the outlet fans on  
2 the high speed. Then, I found out a lot of plants  
3 don't have that capability. They would have to rewire  
4 that.

5 I am just wondering if newer plants, if  
6 anybody has procedures like that, or if newer plants  
7 have that kind of capability, if that is part of  
8 training. I have been informed that some places with  
9 real new plants outside of the U.S. such things are  
10 even built in as automatic systems.

11 If anybody can tell me anything about  
12 that, I would be interested, but, you know, it is not  
13 really relevant to what we are doing here, except  
14 underfed fires there might be a basis for it that  
15 would stand up in regulatory review, if you had some  
16 kind of process like that.

17 MR. McGRATTAN: Well, oftentimes,  
18 compartments in plants are sufficiently large, such  
19 that that kind of tactic that will work on surface  
20 ships may not work in a plant because of the large  
21 volumes involved.

22 MEMBER BLEY: Just because of the openness  
23 in there.

24 MR. McGRATTAN: Yes.

25 MEMBER BLEY: Yes. That kind of makes

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1 sense.

2 MR. SALLEY: The concept you are talking  
3 about, smoke management --

4 MEMBER BLEY: Yes.

5 MR. SALLEY: -- there's whole textbooks  
6 written on that. Jim Milke, as a matter, one of the  
7 reviewers, wrote one of the classics on that. And  
8 Maryland has a whole class just on that.

9 You are talking about a sandwiching where  
10 you increase the pressure in the surrounding  
11 compartments and evacuate.

12 MEMBER BLEY: Right.

13 MR. SALLEY: As far as just modeling the  
14 knowledge, what we would do in the plants, you know,  
15 it would all be up to the operators, you know, what  
16 they wanted to stop and start and how they wanted to  
17 manage the HVAC system in coordination with the fire  
18 brigade.

19 And the other thing, too, is you are going  
20 to have to watch your fire dampers. If any of those  
21 dampers closed off in the ventilation system, they are  
22 going to take out of the game. So, again, that would  
23 be very plant-specific as to how the fire brigade and  
24 the operators --

25 MEMBER BLEY: I take it that hasn't come

1 up as an issue in anything that has been going on so  
2 for?

3 MR. SALLEY: Like I said, I know what they  
4 have done in the past.

5 MEMBER BLEY: Okay.

6 CHAIR STETKAR: Let me ask you one more  
7 question. And that is, the NUREG -- it is sort of  
8 related to this scope of validation and  
9 verification -- the NUREG in several places mentions  
10 the use of the codes THIEF and FLASH-CAT, in  
11 particular, for modeling cable fires, in the sense of  
12 pretty much endorsing their use. Those codes, to my  
13 knowledge, haven't been put through a formal V&V  
14 process.

15 And the question is, is this NUREG's  
16 endorsement of the use of those codes sufficient, so  
17 that the NRR folks would say, oh, okay, these folks  
18 used THIEF and FLASH-CAT for cable fires, which are  
19 pretty important for most real-fire analyses?

20 MR. McGRATTAN: Right. As part of their  
21 development, those -- and I will call them, they are  
22 really algorithms -- were verified and validated as  
23 part of the development. So, the NUREGs that describe  
24 them also provide the validation basis for their use.

25 CHAIR STETKAR: Well, but people

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1 understand that there are five codes now that have  
2 undergone V&V.

3 MR. McGRATTAN: Right.

4 CHAIR STETKAR: And that is sort of the  
5 suite that people can use.

6 MR. McGRATTAN: And THIEF and FLASH-CAT  
7 would be algorithms that could be used within any one  
8 of them. So, for example, we have embedded within FDS  
9 and CFAST these algorithms.

10 CHAIR STETKAR: Well, wait a minute,  
11 Kevin. All the algebraic models in FDTs and 5, Rev.  
12 1, are simply, you know, they are empirical  
13 algorithms.

14 MR. McGRATTAN: Right. Correct.

15 CHAIR STETKAR: And yet, the only way that  
16 people can use those is to take the specific  
17 algorithms that have the checkmark in 1824 that says  
18 they have gone through V&V.

19 MEMBER BLEY: Without justification,  
20 further justification.

21 CHAIR STETKAR: Without further  
22 justification.

23 MR. JOGLAR: As a fire-modeling analyst,  
24 I know the NUREGs that were written describing THIEF  
25 and FLASH-CAT, and I referenced those as having the

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1 validation there. So, I guess what --

2 CHAIR STETKAR: What I am talking about is  
3 you guys are in research. Research is really useful.  
4 I am a guy out in the plant. I have a manager who  
5 wants me to justify the transition to NFPA 805. I  
6 have to do analyses to support that. Some of my  
7 analyses have to use verified and validated fire-  
8 modeling codes, and I have to have that analysis  
9 reviewed and approved by the Nuclear Regulatory  
10 Commission, such that I get my license amended. That  
11 is the reality.

12 The question is, if I am a fire modeler in  
13 the plant, can I use THIEF and FLASH-CAT and have my  
14 approval or not?

15 Hi, Alex.

16 (Laughter.)

17 MR. KLEIN: Hi, John.

18 Okay. Just one clarification. We do not  
19 review and approve. We determine acceptability of the  
20 models --

21 CHAIR STETKAR: Okay. I'm sorry.

22 MR. KLEIN: -- in accordance with NFPA  
23 805.

24 With respect to a licensee's use of, say,  
25 FLASH-CAT or THIEF, or anything -- call it an XYZ fire

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1 model -- if a licensee wants to propose use of a fire  
2 model to the regulator, NRR, and, say, transition to  
3 NFPA 805, we look for that licensee to be able to  
4 demonstrate to us that they have done proper  
5 verification and validation of that model, and that  
6 they have used that within the applicable range of  
7 that model.

8 So, we will question that licensee. So,  
9 with respect to THIEF and FLASH-CAT, I think it has  
10 been used at one of the licensees. So, we are  
11 certainly asking those types of questions of the  
12 licensee.

13 CHAIR STETKAR: What I was asking, though,  
14 Alex, is what I think I understand. We now have a  
15 NUREG-1824. It is not on the street, but people are  
16 being trained now on the principles of it.

17 It refers to two fire models that have  
18 corresponding NUREGs documenting their development,  
19 the basis for them, the models themselves. And it has  
20 been asserted that those NUREGs can serve as a  
21 verification and validation of those models.

22 If I want to use one of those models, can  
23 I simply now refer to this set of NUREGs in the way  
24 that I can refer to 1824, as long as I justify that my  
25 application is within the V&V range of the five models

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1 in 1824? Or, if I want to use THIEF and FLASH-CAT, do  
2 I need to build my own case 47 times because  
3 individual applicants will have 47 different problems  
4 for those models? That is the concern.

5 MR. KLEIN: Here is my personal opinion,  
6 John. I don't have the details on what is in the  
7 NUREG for THIEF and FLASH-CAT in terms of verification  
8 and validation. I have got other folks who are much  
9 closer to it than I am.

10 But here is kind of a generic response:  
11 if there is no adequate justification in the THIEF or  
12 the FLASH-CAT NUREGs in terms of demonstrating to us,  
13 as the regulator, that they have been adequately  
14 verified and validated in accordance with the criteria  
15 that has been established in 1824, then we will look  
16 for that licensee. Whether it is 44 times or more, we  
17 will ask each individual licensee who utilizes that  
18 for them to be able to demonstrate to us that they are  
19 using a model that is adequately verified and  
20 validated.

21 CHAIR STETKAR: Okay. Thanks. That helps  
22 a lot.

23 MR. KLEIN: Okay.

24 CHAIR STETKAR: Thanks.

25 MR. SALLEY: If I could just follow up

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1 with that, John, one last point, you have to remember  
2 that THIEF and FLASH-CAT, THIEF came out of CAROLFIRE  
3 and FLASH-CAT is coming out CHRISTIFIRE. Both of  
4 these research programs were done after 1824 was  
5 already issued. So, those two algorithms didn't exist  
6 when we were doing 1824.

7 Now, as you are going to hear at the end  
8 of the day, when this project is complete and we move  
9 into the next phase, one of the first things we are  
10 going to want to do is go back to 1824 and again  
11 advance the state of the art. So, that is where we  
12 will be bringing in FLASH-CAT and THIEF.

13 As a matter of fact, a project Dave is  
14 working on the side for the 1805 FDTs, he has one of  
15 the codes up, FLASH-CAT; he has one of the codes up,  
16 THIEF. When we do the V&V again, he will issue those,  
17 do the V&V, and they will come out.

18 So, this is going to be a repetitive  
19 process. CHRISTIFIRE 3 is going to develop some more  
20 new acronyms or algorithms --

21 (Laughter.)

22 I do acronyms; you do algorithms. Yes, we  
23 kind of watch our job descriptions.

24 (Laughter.)

25 But, for like vertical trays, you will be

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1 seeing that we will be working in 2013 and 2014. So,  
2 this process never ends. It keeps --

3 MEMBER BLEY: This is where 1824 becomes  
4 a living document, I think.

5 MR. SALLEY: Exactly. And like I said,  
6 our next hurdle you are going to hear at the end of  
7 the day for me is that I want to go back to 1824 and  
8 let's expand it. We now have a better idea of where  
9 we need to open the V&V up. We know where we need to  
10 go do some more experiments. So, that is where we  
11 need to get on with the research.

12 MR. JOGLAR: Although the same way we had  
13 examples where we would shrink the rooms to make them  
14 fit the V&V, I think we also have examples where the  
15 validation is outside 1824, and we are referencing it.  
16 And that would be what THIEF and FLASH-CAT --

17 MR. SALLEY: As a final thought, too, I  
18 mean, because we have got the same people working on  
19 this, Kevin obviously understands the importance of  
20 uncertainty in V&V. So, when we develop things like  
21 THIEF and FLASH-CAT, as a part of the development, we  
22 do the V&V in that same document.

23 So, if you pull Volume 3 of CAROLFIRE, you  
24 will see how we did the one-dimensional heat transfer  
25 that Kevin did to create THIEF, and then how it was

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1 validated with other experiments in that series  
2 independently. So, we work it together. I mean, we  
3 understand the process.

4 CHAIR STETKAR: Okay. Thanks, Mark.

5 Dave?

6 MR. STROUP: Okay. Well, this all ties  
7 in, and a number of the issues that have been  
8 discussed are one reason why or the big reason why it  
9 has taken us so long to get to the point where we are  
10 at right now.

11 Prior to submitting the document for  
12 public comment back in the latter part of 2009/early  
13 2010, we gave it to a number of peer reviewers. Based  
14 on their comments, we rewrote the document, again, a  
15 lot of it having to do with eliminating redundancy and  
16 improving the flow.

17 When we released the document for public  
18 comment in 2010, we got approximately 200 comments.  
19 Many of them we probably should have expected. As I  
20 forget whether it was Kevin or Francisco said earlier,  
21 actually doing a V&V on real scenarios or bringing the  
22 V&V results in is very hard. In some cases, perhaps  
23 all the cases, we didn't do as much homework as we  
24 should have, and there was not the substance that we  
25 would have liked in that early draft, and people

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1 called us on it.

2 And also, just dealing with applications  
3 that were outside the verification and validation  
4 range, in a lot of the early cases I think we may have  
5 just dismissed that a little too offhandedly.

6 We dealt with all of those comments. We  
7 added several more practitioners to the team. One of  
8 the other underlying public comments we had, or  
9 perhaps I had a vision at the time, that we needed to  
10 do some level of basic discussion of the various areas  
11 where fire modeling might be used within the nuclear  
12 arena, you know, fire PRA, 805, STP process, and the  
13 like.

14 Well, we initially devoted whole chapters  
15 to some of those topics, which ended up being too  
16 much, and some people said, "There's not enough here  
17 for us to understand anything" or "There's too much  
18 here for an introduction." So, we eliminated a lot of  
19 that and tried to focus it solely on just the fire  
20 models.

21 In 2011, we re-released the document for  
22 public comment. And also, in addition, NRR took the  
23 document and sent it to one of their 805 contractors,  
24 who also reviewed the document. We got one public  
25 comment and numerous comments from the NRR contractor,

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1 which we ultimately resolved.

2 NRR then sent the revised document and the  
3 resolution of comments back to their contractor for  
4 any additional comments. And we resolved all of  
5 those.

6 Just very briefly, Chapter 1, it talks  
7 about a lot of the background information that I have  
8 been discussing here.

9 We also, as I think has been discussed  
10 here briefly, too, we also try to point out to the  
11 user that you need a certain level of background in  
12 order to be able to use these fire models effectively.  
13 And we provide some guidance and I guess, to some  
14 extent, enough buzzwords to try to make people who  
15 might not have the proper background a little  
16 concerned that maybe they shouldn't be doing this, if  
17 they don't have enough knowledge.

18 We also provide some suggestions for where  
19 they can obtain additional training: the Society of  
20 Fire Protection Engineers' short courses, the EPRI  
21 6850 training, and similar types of training courses.

22 There is also a brief basic review of fire  
23 dynamics theory and the various categories of fire  
24 models, so that everybody understands the terms that  
25 we are dealing with.

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1                   And then, finally, the chapter goes  
2 through a brief discussion of how the report is  
3 organized and a little bit of discussion of what the  
4 appendices are intended to do.

5                   CHAIR STETKAR: Dave, before you slip to  
6 Chapter 2, I thought that, as kind of an overview,  
7 Chapter 1 was generally pretty good until I got to  
8 Section 1.7 that talks about multiple spurious  
9 operation fire-modeling applications. That section  
10 addresses a topic that everybody doing either a  
11 deterministic or a risk-informed fire assessment  
12 struggles with mightily.

13                   The discussion in this section seems to be  
14 entirely oriented to deterministic fire analyses. It  
15 goes into detailed discussions about green box and  
16 orange box, combinations of MSOs. It talks about  
17 protection of the safe-shutdown path. It talks about  
18 Reg Guide 1.189 and the guidance in NEI 00-01  
19 regarding deterministic fire analyses.

20                   That is all well and good if I am doing a  
21 deterministic fire analysis. It is not all that  
22 useful for those of us who are out there doing risk-  
23 informed analyses that don't think about green boxes  
24 and orange boxes, and don't think about safe-shutdown  
25 paths, and don't think about the sort of contrived

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1 assumptions that you use in a deterministic fire  
2 analysis.

3 So, I was curious why almost two pages of  
4 guidance addressed only deterministic fire assessment  
5 of multiple spurious operations and really don't  
6 mention anything about how people do it in the risk-  
7 informed world. And the reason I bring that up is  
8 other sections are pretty good about doing that in  
9 that Chapter 1. It says, well, in a deterministic  
10 analysis, you might do it this way; in a probabilistic  
11 analysis, you might have to do it a little bit  
12 differently. This section doesn't.

13 MR. JOGLAR: In my opinion, that is a good  
14 comment.

15 (Laughter.)

16 CHAIR STETKAR: I would really recommend  
17 that you look at that because it's --

18 MR. JOGLAR: Yes. Generally -- and you  
19 guys can agree or disagree with me -- we see fire  
20 modeling as this is the guidance on fire modeling. In  
21 my opinion, if you apply it to solve one of the  
22 deterministic problems or you apply it for fire PRA,  
23 the guidance should apply. So, if that is not  
24 mentioned in that section, we probably have to improve  
25 it.

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1 CHAIR STETKAR: Yes, it is not, and I  
2 would encourage you to take a look at it. Because it  
3 doesn't, for example, mention Reg Guide 1.205 that is  
4 the companion with 1.189. And NEI 00-01 actually does  
5 contain some guidance about the probabilistic modeling  
6 of multiple spurious operations, except that the stuff  
7 that is excerpted is kind of only the deterministic  
8 side of the coin. So, if you could --

9 MR. JOGLAR: Yes, I think we agree with  
10 your comment, but the point, as I said, is that our  
11 guidance in the fire model should apply to both, and  
12 our intent would be that that section include that  
13 thought in there.

14 CHAIR STETKAR: Okay. Good. Thanks.

15 MR. STROUP: Finally, the guts of Chapter  
16 2 is to spell out the fire-modeling process. We  
17 identified a six-step process of refining goals and  
18 objectives; characterizing the fire scenarios;  
19 selecting the fire models; basically running the fire  
20 models to calculate the fire-generated conditions, and  
21 specifically spelling out that you need to conduct a  
22 sensitivity and uncertainty analysis; and finally, the  
23 documentation of the analysis.

24 CHAIR STETKAR: A couple of minor things  
25 on Chapter 2, actually several, but they are kind of

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1 minor. But it is important, when you write a  
2 document, to kind of understand how people might  
3 interpret or misinterpret the words.

4 In Section 2.2.1, Step 2, "Characterized  
5 Fire Scenarios," there is a discussion about the  
6 maximum expected fire scenario versus the limiting  
7 fire scenario in the context of NFPA 805 definitions  
8 of those scenarios. There is a statement that says,  
9 "The input values necessary to determine the MEFS,"  
10 which is the Maximum Expected Fire Scenario, "should  
11 be best estimates of the actual parameter values. The  
12 inputs for the LFS," Limiting Fire Scenarios, "can  
13 exceed those which are probable or even possible."

14 Now, as kind of somebody who struggled  
15 with this, I think I understand what you might be  
16 saying, but I am not sure if everybody does. In other  
17 words, if I characterize a best estimate as the median  
18 -- or I normally characterize it as the mean, but I  
19 recognize that some people also characterize it as the  
20 median -- of an uncertainty distribution, and look at  
21 this as guidance to say, well, to develop the MEFS, I  
22 should use the best estimate, I can interpret this as  
23 saying, well, I'll take the mean value of the  
24 uncertainty distribution.

25 I don't think that is the intent of NFPA

1 805. I think the intent is to take the upper bounds  
2 of those uncertainty distributions, and NFPA 805  
3 usually uses the 98th percentile to characterize those  
4 upper bounds, and use those upper bound values to  
5 characterize the largest fire that could occur within  
6 this location within the uncertainty range of the  
7 parameters that I have to characterize that fire, not  
8 the best estimate, but a conservative estimate, and  
9 see how big that is. Then, compare it to the size of  
10 the fire that is necessary to damage the critical set  
11 of equipment. And if you have adequate margin there,  
12 you can screen the area out.

13 The important thing is that people use  
14 this as a screening criterion. So, if people are  
15 using the, indeed, best estimates, the mean values, to  
16 do that calculation, you are calculating perhaps much,  
17 much larger margins than is the intent of NFPA 805.

18 I don't know if you have any comments on  
19 that, but it was --

20 MR. STROUP: I think I would default to  
21 Francisco's previous comment. I think that is a good  
22 comment.

23 I know in preparing for this meeting, I  
24 was re-reading some of those sections and realized  
25 that in a lot of cases I think some of the language

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1 was pulled in directly out of the document, out of  
2 805, and probably was not really written in a plain,  
3 understandable fashion to say what it really was  
4 intended to mean.

5 CHAIR STETKAR: The folks who wrote NFPA  
6 805 did a very good job in many areas. They weren't  
7 quite as clear as they should have been in many other  
8 areas. And since this is now a Users' Guide to help  
9 to clarify some of those issues, it would be good if  
10 it did.

11 MR. JOGLAR: I think, from the industry  
12 side, if you are using it in the PRA where those terms  
13 don't apply directly, there is guidance. You know,  
14 you use the screening values.

15 When you go into the deterministic side,  
16 I agree with you, even in the industry, it is not  
17 clear what the maximum expected is. My opinion is  
18 that it may end up being decided on a case-by-case  
19 basis as NRR reviews, individual applications, to see  
20 if the margin is okay.

21 CHAIR STETKAR: Well, but if there is some  
22 general guidance --

23 MR. JOGLAR: Right, right.

24 CHAIR STETKAR: -- for example, some  
25 recommendation that says, you know, use the 98th

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1 percentile or the 2nd percentile, depending on which  
2 extreme gives you the most conservative results of the  
3 underlying uncertainty distributions, I think this  
4 document ought to at least present that sort of  
5 general approach, rather than just saying, "Use the  
6 best estimate."

7 MR. JOGLAR: Although I know I am not  
8 going to be answering your point with this, as an  
9 example, in the industry debating what is the maximum  
10 expected, we have postulated the question: let's say  
11 in a room I have combustible controls that prohibit  
12 hot-work activities. Do we have to postulate a hot-  
13 work fire as a maximum expected if I have rules that  
14 prevent that? It is that type of question that we  
15 don't have -- you know, I agree with you.

16 CHAIR STETKAR: But that is a different,  
17 that is sort of a black/white, go/no-go screening  
18 criterion. I am talking about, given the fact that  
19 you have needed to include a set of ignition sources,  
20 you have needed to characterize the compartment by  
21 some geometry, some ventilation, or whatever, and now  
22 burn a fire, there are uncertainty distributions for  
23 many of those parameters, perhaps not for the volume  
24 of the room, but most of the others.

25 MR. JOGLAR: Yes, the ventilation, you

1 would use the normal operating for that room, right,  
2 for example?

3 CHAIR STETKAR: Well, that's my whole  
4 point. If the range of ventilation flow could span a  
5 factor of two, you don't necessarily use the median  
6 value of that to develop your Maximum Expected Fire  
7 Scenario, because that might give you optimistic  
8 screening criteria. You might, indeed, calculate a  
9 larger margin than the intent of NFPA 805.

10 I know you are standing there, Alex. I am  
11 not ignoring you.

12 MR. KLEIN: You've got eyes in the back of  
13 your head, John.

14 (Laughter.)

15 CHAIR STETKAR: No, no, you're just --

16 MR. KLEIN: I haven't waved my arms or  
17 anything.

18 (Laughter.)

19 CHAIR STETKAR: That's okay. In our  
20 Subcommittee Chairman training, they tell you to be  
21 sensitive to this.

22 MR. KLEIN: Right, very sensitive. Thank  
23 you.

24 At a high level, I think the only comment  
25 I want to make here is that we will have an

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1 opportunity, I think, to discuss some of these  
2 questions that you are bringing up here when we come  
3 to your Subcommittee in the July timeframe.

4 I am not saying don't ask these questions  
5 today. I mean --

6 CHAIR STETKAR: No, no.

7 MR. KLEIN: But I think certainly it gives  
8 us, it gives NRR some indication as to what the  
9 interests are in terms of what is it that we look at  
10 when we receive these license amendment requests.

11 CHAIR STETKAR: What I am trying to do,  
12 though, Alex, obviously, is I am trying to bridge, in  
13 my opinion, I am trying to sort of bridge places where  
14 I perceive there may be gaps between either explicit  
15 or not-clearly-presented recommendations in this NUREG  
16 versus my understanding of the expectations from  
17 NUREG/CR-6850 and NFPA 805 -- and I am glad you are  
18 here -- and what I presumed that the staff would be  
19 looking for in their reviews of actual submitted  
20 analyses.

21 So, if the staff interprets the Maximum  
22 Expected Fire Scenario, which is used for screening,  
23 more in the deterministic world than the NFPA 805 --  
24 but I think the NFPA 805 people use a combination of  
25 deterministic and risk-informed methods.

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1 MR. KLEIN: When we come to you in July --  
2 at a high level, what licensees are doing is the way  
3 they are utilizing fire modeling now is they are using  
4 an approach where they use the fire modeling as part  
5 of a fire PRA, if you will. So, it is part and parcel  
6 of that, to screen out some of these scenarios in  
7 these areas.

8 And if they need to involve additional  
9 fire modeling, say FDS or CFAST type of fire modeling,  
10 because they don't screen out, that is the next step  
11 that a lot of licensees take because it doesn't screen  
12 out.

13 And that is something that I think we will  
14 bring to you in July. We will have, I think, a fairly  
15 lengthy discussion on what it is that licensees do and  
16 how is it that the staff reviews those applications.

17 CHAIR STETKAR: Okay. Good. Thanks.

18 I will still recommend, just as a  
19 takeaway, just take a look at how people might  
20 interpret that phrase "the use of the best estimates  
21 to calculate the Maximum Expected" --

22 MR. JOGLAR: In my own experience doing  
23 that for outside of PRA, we took an approach, but with  
24 the understanding that perhaps when it gets to the NRR  
25 we will get questions and discussions because it is

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1 not clear.

2 CHAIR STETKAR: Well, okay. I guess we  
3 need to be cognizant of the time here, so we don't run  
4 too awfully long because there is a lot of material to  
5 cover.

6 But I think part of our role here is to  
7 perhaps be sensitive to the fact that we have several  
8 documents that on the cover say, "U.S. Nuclear  
9 Regulatory Commission," and perhaps a lot of people  
10 don't necessarily understand the subtleties of the  
11 difference between Research and NRR. And they presume  
12 that, indeed, a lot of these types of discussions have  
13 gone on, such that recommendations in one NUREG don't  
14 necessarily cause problems for people in other types  
15 of applications. So, let me just leave it at that.  
16 I think I kind of made the point.

17 Let's see. I had a few things here, but,  
18 unfortunately, my notes are all messed up. So, you  
19 will have to bear with me.

20 Oh, this is just a question. It is really  
21 good. One thing I really liked, there is a Section  
22 2.2.3 that makes extensive reference to NUREG/CR-6738,  
23 which is "Risk Methods/Insights Gained from Fire  
24 Incidents". It says, look, when you start  
25 characterizing your fires and building your analysis

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1 and your models, it is really good to go back and look  
2 at what has happened in the industry.

3 You know, Mark kind of prefaced the whole  
4 meeting today by saying there's no substitute for  
5 learning from real fire analyses or real fires that  
6 have really occurred.

7 That is really good. The bad thing is  
8 that NUREG/CR-6738 was published in September of 2001.  
9 And looking at the fire, it includes 25 fire events,  
10 which is a reasonable sampling. But the latest one  
11 was April 1996. So, it includes no information about  
12 fires that have occurred over the last 15 years or so.

13 And most of the fires that are in that  
14 NUREG date back to the eighties, which kind of  
15 preceded a lot of the improvements to both fire  
16 protection and suppression systems and procedures and  
17 plant sensitivity to fires. And also, unfortunately,  
18 suffered in many cases from limited documentation in  
19 terms of what was written about the fires.

20 My question is, does RES currently have a  
21 plan to update that NUREG? And if you don't, maybe  
22 you ought to think about it, because we have had a  
23 number of kind of interesting fires that have occurred  
24 over the last 20 years. Documentation is a lot  
25 better. Sensitivities to documenting what has gone

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1 on, the staff's and the industry's sensitivity to  
2 understanding fires has been enhanced quite a bit.

3 And it strikes me that capturing some more  
4 of that recent experience would help people, not in  
5 the near-term, obviously, but I was just curious  
6 whether Mark --

7 MR. SALLEY: That is a good point, and we  
8 will use that as a takeaway. I mean, there's a number  
9 of places and a number of activities that are ongoing.  
10 I can remember back in my NRR days, for example, there  
11 was an Information Notice or two that we would put out  
12 when we would see a few new fires.

13 Obviously, Rick is working on the big  
14 database. We are trying to get our arms around the  
15 database for all the fires.

16 We also have a program for international.

17 But going back to this one, and maybe  
18 doing an update, John, it is a good idea. We will  
19 take a look at that. I will discuss that with NRR.

20 CHAIR STETKAR: I mean, it doesn't have  
21 any impact on getting this NUREG out the door. And I  
22 think it is really good guidance. It is just a matter  
23 of looking at fires that are 25-30 years old may not  
24 be all that relevant.

25 MR. JOGLAR: Some of the interesting fires

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1 after that are in NUREGs, like the high-energy arcing  
2 faults. We have captured that guidance in 6850, for  
3 example. So, it doesn't necessarily mean that we have  
4 missed those interesting fires in subsequent  
5 documents, but they are not compiled in a single  
6 document looking for risk insights that that document  
7 was doing.

8 CHAIR STETKAR: Okay. A minor comment.  
9 Section 2.2.8, again, I am a PRA guy. So, I like to  
10 get right terminology. In this section, it says,  
11 "When fire modeling is used to support a fire PRA, the  
12 heat release rate, HRR, for a source fire may be  
13 represented as a frequency distribution. In this  
14 case, depending on the type of analysis, a  
15 conservative screening value may be selected; for  
16 example, the 98th percentile peak heat release rate,  
17 or the effects may be represented by using multiple  
18 points on the frequency distribution."

19 It is not actually a frequency  
20 distribution. It is a conditional probability  
21 distribution. It is just a minor point, but there is  
22 going to be a theme here in my comments through the  
23 rest of the afternoon that, when you are talking about  
24 uncertainties, when you are talking about probability  
25 distributions, you ought to use the correct

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1 terminology. Otherwise, all it does is cause more  
2 confusion.

3 Oh, and here's something I don't  
4 understand, only because I am not a fire modeler. I  
5 don't do this stuff. I mean, I am learning more  
6 things than I ever knew before, or probably ever  
7 wanted to know.

8 There is, and it is Equation 2-8 -- I  
9 don't know if you have the document in front of you,  
10 but it is -- let me pull up the equation here. I am  
11 not going to find it quickly. But it is Equation 2-8.

12 MEMBER ABDEL-KHALIK: Ceiling jet ratio.

13 CHAIR STETKAR: Yes, it is for the ceiling  
14 jet ratio.

15 MEMBER ABDEL-KHALIK: Page 226.

16 CHAIR STETKAR: Thank you.

17 That equation -- and this is probably my  
18 lack of understanding or familiarity -- that equation  
19 says the ceiling jet ratio is the ratio of the  
20 horizontal distance within the ceiling jet from the  
21 fire center line -- so, it is the spread at the  
22 ceiling -- divided by the sum of the enclosure height  
23 plus the fire base height.

24 It would strike me that, shouldn't the  
25 base height be subtracted from the enclosure height?

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1 I mean, aren't you measuring the spread, the  
2 horizontal spread of the flame divided by,  
3 essentially, the vertical plume height, which would H  
4 sub c minus H sub f rather than the sum of the two?

5 MR. McGRATTAN: HMF is the height of the  
6 fire; HMS is the enclosure height. Yes, it should be  
7 a minus sign.

8 CHAIR STETKAR: My job is done here.

9 (Laughter.)

10 MR. McGRATTAN: I think the confusion was,  
11 at some point, H sub c was the height of the cabinet.  
12 That is probably why it got stuck there. That is a  
13 good point, yes.

14 CHAIR STETKAR: Thanks.

15 MR. McGRATTAN: Yes.

16 CHAIR STETKAR: It shows you I actually  
17 read these things.

18 (Laughter.)

19 MR. McGRATTAN: Where were you during the  
20 public comment period?

21 (Laughter.)

22 CHAIR STETKAR: I don't do public  
23 comments.

24 That is all I had on Chapter 2.

25 Did any other Members have any comments or

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1 questions on Chapter 2?

2 (No response.)

3 With that, we are ready to go to the next  
4 one.

5 MR. STROUP: With that, I will turn it  
6 over to Francisco to go to Chapter 3.

7 CHAIR STETKAR: Francisco, how long do you  
8 think it will -- well, we will wait. Just recognize  
9 that sometime in the next 15-20 minutes we are going  
10 to take a break.

11 MR. SALLEY: Why don't you take it now?

12 CHAIR STETKAR: Is it better to take it  
13 now, you think?

14 MR. SALLEY: Yes, before Francisco starts.

15 CHAIR STETKAR: Okay. Let's take a break.  
16 We will recess until five minutes to 3:00.

17 (Whereupon, the foregoing matter went off  
18 the record at 2:38 p.m. and went back on the record at  
19 2:55 p.m.)

20 CHAIR STETKAR: Let's come back into  
21 session and hear about Chapter 3.

22 MR. JOGLAR: My name is Francisco Joglar.  
23 I work for Hughes and Associates. That is recent.  
24 Most of this work, I was doing it while working for  
25 SAIC.

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1 I have been on the Writing Committees for  
2 the V&V 1824, for 6850, and now in this report. And  
3 also, I have done a lot of work for the industry in  
4 NFPA 805 transitions and fire PRAs. So, that is my  
5 background.

6 As Dave said, any questions, please feel  
7 free to interrupt.

8 So, we said earlier that we wanted to  
9 focus on the user. In our opinion, we had the V&V  
10 work, NUREG-1824, that focused on the models. So, we  
11 wanted to give focus to the user, and Chapter 3 is the  
12 very first step in doing that.

13 As Dave said, we have defined a process in  
14 Chapter 2 to do fire modeling, and that process is  
15 general engineering practices; introduction, your  
16 assumptions, all that kind of stuff, that it is pretty  
17 general for engineering process.

18 So, Chapter 3 is the first attempt in our  
19 guide to actually go and start providing guidance to  
20 the user of these tools. The approach we took in  
21 Chapter 3 is to keep it qualitative, very general.

22 And we did that because, further on, we  
23 have very detailed examples where all the complexities  
24 of fire models are treated. We wanted these to serve  
25 as a qualitative overview of the process. We think it

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1 helps those most common applications in the industry  
2 now, which is NFPA 805 and the fire PRAs.

3 So, the areas in which we tried to provide  
4 this qualitative guidance include heat release rate,  
5 plant area configuration, ventilation effects,  
6 targets, and intervening combustibles. If you look at  
7 these elements, these are the elements that are mostly  
8 defined when we do fire modeling. That is where most  
9 of the justification and references to operating  
10 conditions from the plant and plant drawings go.

11 Some of them come directly out of plant  
12 operating procedures and drawings, like plant  
13 configuration and ventilation effects, location of  
14 targets. Some others require going into research  
15 reports like NUREGs and fire protection engineering  
16 literature to find heat release rate values, proper  
17 use of intervening combustibles, et cetera.

18 CHAIR STETKAR: Before you switch to the  
19 examples, let me ask you a question about, in Section  
20 3.1.1, they talk about heat release rate. You don't  
21 have to look it up. Let me just bring up the target,  
22 the statement.

23 You talk about why you probably shouldn't  
24 model the incipient stage of fire growth. The  
25 statement that is made, which is true, it says,

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1 "Because of the uncertainty in the intensity of the  
2 fire during this stage and the exact time that a fire  
3 will transition to a significant fire, the incipient  
4 stage is often not considered in the analysis."

5 This is important because people are  
6 trying to take credit for incipient fire detectors.  
7 So, modeling the incipient stage of the fire gives  
8 them a little more time for detection and either  
9 automatic or manual suppression.

10 I think there is probably, in practice, a  
11 more fundamental reason, which actually makes the  
12 problem a little bit more difficult. That is, when  
13 the fire database is developed, there is extensive  
14 screening that is done to toss out insignificant  
15 fires, so that only significant fires are retained.  
16 And it is not clear to me, if you retained all of the  
17 fires, regardless of how big they were or how  
18 significant you expected they might become, then there  
19 would be, I think, perhaps much better justification  
20 for modeling the full-ignition-to-actual-full-  
21 development progression of those fires.

22 But if you are tossing out some number of  
23 very small or insignificant fires, it is not at all  
24 clear how well you are justified now developing a  
25 model that says, well, I've got ignition, so I can now

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1 model the incipient stage of the fire. And you may  
2 want to acknowledge that.

3 And I bring that up only because EPRI is  
4 kind of the curator these days of the database that  
5 most people use, and they are heavily involved in that  
6 screening process and the screening criteria. So, you  
7 guys may want to think about that a little bit.

8 MR. WACHOWIAK: Yes, this is Rick  
9 Wachowiak.

10 Yes, I think we will think about it. I am  
11 not sure that the thrown-out piece does exactly what  
12 you are talking about because the fires that are  
13 retained all had an incipient phase. They just got to  
14 the point where they grew.

15 Now if you are saying to fire model so  
16 that you can detect and remove all of those with a  
17 high probability during the incipient phase, maybe  
18 that is what you are talking about there. I think  
19 that is the consideration there, because we don't want  
20 to give too much credit to that because we already  
21 know that the frequencies that we are using are based  
22 on the fires that had a chance to grow.

23 CHAIR STETKAR: That were through that,  
24 essentially.

25 MR. WACHOWIAK: Right, right.

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1 CHAIR STETKAR: Or partially through that  
2 phase.

3 MR. WACHOWIAK: But if you look in the  
4 database itself, though, many of the fires that grew,  
5 the reported durations were much longer than the  
6 T-squared, 12 minutes, whatever the right timeframe is  
7 for the fuel package. They were longer than that.  
8 And some of those fires really didn't get very big  
9 yet. They hadn't damaged other things.

10 So, I will think about how you would do  
11 it, and --

12 CHAIR STETKAR: I just bring it up as a  
13 topic.

14 MR. WACHOWIAK: Right.

15 CHAIR STETKAR: It just struck me because  
16 I know that there is some screening that has gone  
17 on --

18 MR. WACHOWIAK: Right.

19 CHAIR STETKAR: -- and the notion that  
20 says, well, now for some fires, I can perhaps use a  
21 model to go back through the incipient. I mean, here  
22 it is says, generally, you shouldn't do that, but it  
23 just says, generally, you shouldn't do that.

24 MR. JOGLAR: In our fire PRA trainings,  
25 that is the guidance that we provide from a purely

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1 modeling perspective. We don't know how long it is,  
2 and we are not going to get anything new out of the  
3 model for modeling in an incipient thing. We are not  
4 going to change room conditions if we add that.

5 So, that is why the second point is that,  
6 yes, there are now, through that safety process,  
7 clarification on how to credit, quote/unquote,  
8 "credit" a fire incipient detection system in the  
9 room, and the guidance I think focuses on what you are  
10 saying. Now we are detecting something that is not a  
11 fire. It can become a fire. We have to treat it  
12 differently.

13 CHAIR STETKAR: Well, and the fact that  
14 the database for the frequency of those things,  
15 whatever those things are that I am now developing a  
16 model for, the frequency of those has already, I  
17 think, subtracted out some of those things that were  
18 not fires, that now you are trying to take some of the  
19 fires that were fires and say, well, we could detect  
20 them and extinguish them before they were.

21 MEMBER BLEY: In fact, when we had -- who  
22 was it? -- Paul Amico and some others who were working  
23 for EPRI here, they had a group working on doing  
24 exactly that.

25 MEMBER SCHULTZ: That database is skewed.

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1 So, caution needs to be provided.

2 CHAIR STETKAR: And all I am saying, I  
3 think I would just recommend that you kind of revisit  
4 that notion here a little bit because, again, it is a  
5 Users' Guide. It is developed by fire modelers, and  
6 that's good. It is a good Users' Guide for fire  
7 modelers, but it will be used by people who are  
8 thinking about broader things than only the fire  
9 models.

10 MR. WACHOWIAK: That's right, and we  
11 recognize that. And one of the activities in the fire  
12 PRA action matrix for this year is to start looking at  
13 the model that is used for fire growth and include  
14 things like that. I think that might be the Paul  
15 Amico statement here that came out, that we are  
16 working to try to nail that down. But it is certainly  
17 not in a stage right now where we could put it into a  
18 fire model.

19 MEMBER ABDEL-KHALIK: So, where does the  
20 slope of that T-squared growth period come from, just  
21 fitting that part of the experimental data?

22 MR. WACHOWIAK: Yes.

23 MEMBER ABDEL-KHALIK: That's it? And you  
24 just sort of cut it at off at zero, eliminate anything  
25 before that?

1 MR. WACHOWIAK: Right. So, it is  
2 conservative. I would say that.

3 Now the question is, is it the right thing  
4 to use all the time? But that is not the focus of  
5 this work here.

6 MEMBER ABDEL-KHALIK: But, really, where  
7 would a user get the slope of that growth period? I  
8 mean, isn't that sort of fire-dependent?

9 MR. WACHOWIAK: In 6850 --

10 MR. JOGLAR: In 6850, the slopes, the  
11 recommended slope, it is based on the testing we have.  
12 So, we literally looked at a couple dozen of  
13 experiments where we saw the growth and recommended a  
14 value based on looking at them.

15 MR. WACHOWIAK: And the different types of  
16 fires have their own characterization of the fire  
17 growth in 6850. So, there are recommended values to  
18 use, and this document uses those recommended values  
19 at this point.

20 MEMBER ABDEL-KHALIK: Okay.

21 MR. JOGLAR: So, the way Chapter 3 works  
22 is based on a sketch like the one we are presenting  
23 here, where these circles with a number point you to  
24 a specific section of a scenario where guidance is  
25 provided. I will take a minute to quickly run through

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1 the different scenarios we have here.

2 No. 1, we are trying to provide guidance  
3 for fire in cabinets that may be affecting cable trays  
4 that are nearby. Okay? And that is a very common  
5 scenario in switchgear rooms, cable spreading rooms,  
6 et cetera. So, it is the reason why is No. 1.

7 No. 2, we are trying to address guidance  
8 for targets that are away from the fire and may be  
9 exposed to conditions in the room, the far field from  
10 the fire, basically, outside the plume or flames. And  
11 that is why we circle the cable tray emerged in the  
12 smoke or hot gas layer.

13 I point out, also, that in that sketch we  
14 have a multi-compartment arrangement where smoke can  
15 migrate to a second room, and we have guidance for  
16 what we call multi-compartment fires, which is  
17 something that you are supposed to evaluate in fire  
18 PRAs. That is why we have a cable tray circled in the  
19 second room, the room to the right of it. And we have  
20 also vents there, as mechanical ventilation is also  
21 treated in our guide. Okay? So, that is why scenario  
22 No. 3 is a multi-compartment scenario.

23 Scenario No. 4, what we want to highlight  
24 here is not only targets that are away, but it is  
25 complex geometries. Most of our rooms will have

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1 complex geometries, and we have provided guidance on  
2 how to deal with them in the application of different  
3 models.

4 Okay. Scenario No. 5 is the control room  
5 fire, which deserves a lot of analysis in terms of  
6 habitability, when people have to leave the control  
7 rooms. So, we have the full appendix treating these  
8 conditions and solved with different models. So,  
9 control room habitability has a lot of -- it is pretty  
10 prominent in our guide.

11 And finally, Scenario No. 6 -- I should  
12 not have said "finally" -- Scenario No. 6, it is a big  
13 fire in a small room. That would be like a pump oil  
14 fire in the pump room, which is also routinely  
15 addressed in some way in the industry.

16 One scenario that is not listed here is  
17 the big turbine generator fire for which we also  
18 provide guidance. And that becomes important because  
19 in the fire PRA standard there are a few requirements  
20 to treat fire impact to structures. That is actually  
21 guidance that is not in 6850.

22 There are three requirements to address  
23 fire damage to structural steel elements. And we have  
24 added an example in our guide just in case you have to  
25 use a fire model to address those. Sometimes you just

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1 fail the turbine building and that's it. But just in  
2 case you need to analyze it, we have provided an  
3 example for such bigger fires.

4 MEMBER ABDEL-KHALIK: Well, that is, I  
5 guess, Scenario 7, right?

6 MR. JOGLAR: Yes.

7 MEMBER ABDEL-KHALIK: I have sort of basic  
8 questions about scenarios 5 and 7. Because, I mean,  
9 you are careful in discussing some of the other  
10 scenarios about, for example, approximations that  
11 would make the analysis less conservative,  
12 particularly for Scenario 4.

13 But if I look at Scenario 5,  
14 fundamentally, you are saying that the zone model is  
15 okay. And yet, a zone model means that you are  
16 homogenizing the zone. To me, in reality, there will  
17 be areas in which the operators within this control  
18 room in which the operator will be present, in which  
19 the conditions will be a lot worse than the  
20 homogenized result.

21 So, why doesn't that tell me that the use  
22 of a zone model for a scenario like 5 would always be  
23 non-conservative?

24 MR. JOGLAR: Well, we are trying in  
25 Scenario 5, usually, the reason why we solve it is to

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1 determine when we have to leave the control room.  
2 Maybe this doesn't answer your question, but I see it  
3 as, if you have to leave the control room, it doesn't  
4 matter if you can stay in one part of the control room  
5 and not in another. You have to leave.

6 And for that --

7 MEMBER ABDEL-KHALIK: That makes my point,  
8 right? So, you can't do that based on a homogenized  
9 result.

10 MR. McGRATTAN: Well, let me, if I could?

11 MEMBER ABDEL-KHALIK: Yes.

12 MR. McGRATTAN: One of the primary intents  
13 of a zone model calculation is to predict where the  
14 smoke layer is going to be. And chances are,  
15 especially when you are dealing with habitability,  
16 when the smoke layer descends to the height of the  
17 operator, things become inhabitable.

18 So, the zone models are primarily focused  
19 on the layer calculation. But in the example that I  
20 will discuss later in the appendix, we do talk about  
21 the fact that the zone model does produce a uniform  
22 environment; whereas, a CFD model does distinguish  
23 between more severe and less severe parts of the room.

24 MEMBER ABDEL-KHALIK: It is inherent,  
25 right?

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1 MR. McGRATTAN: Yes. So, we have this  
2 strategy of moving from simple calculations, empirical  
3 correlations, to the zone models, to the CFD,  
4 depending on the need for increased complexity. So,  
5 if we find that the physics or the physical  
6 assumptions within the zone model are inadequate for  
7 that particular scenario, we might opt to look at a  
8 CFD model.

9 MEMBER ABDEL-KHALIK: I understand that in  
10 all cases you say that the CFD model will always give  
11 you sort of the best of --

12 MR. McGRATTAN: Right.

13 MEMBER ABDEL-KHALIK: -- the possible  
14 combinations, because you get more resolution --

15 MR. McGRATTAN: Right.

16 MEMBER ABDEL-KHALIK: -- more details.

17 MR. McGRATTAN: But it is not necessary to  
18 run the CFD for every calculation --

19 MEMBER ABDEL-KHALIK: Absolutely.

20 MR. McGRATTAN: -- because you might  
21 discover that you are well within the margin of  
22 safety.

23 MEMBER ABDEL-KHALIK: Right, right. But,  
24 in this particular case, where this is as far as  
25 control room habitability, and when the people have to

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1 leave the control room, it seems to me that saying  
2 that you can do based on a homogenized model is  
3 inherently non-conservative.

4 MR. STROUP: Well, I would argue it the  
5 other way. The advantage of using the zone model is  
6 it is fast. So, if the zone model tells you you have  
7 a potential for a hazard, then you don't have to go to  
8 the CFD model. But by the zone model telling you you  
9 are safe doesn't mean you can --

10 MEMBER ABDEL-KHALIK: Right. This is what  
11 I am concerned about.

12 MR. STROUP: Right. I mean, that is where  
13 I would see the advantage of the zone model, not to  
14 say, well, it is safe, because, as you said, the layer  
15 is distributed over that space.

16 MEMBER ABDEL-KHALIK: It would tell you,  
17 I mean, I understand if it tells you that conditions  
18 are unsafe, then you would go to a 3D model, which  
19 would even be more stringent. But if it tells you it  
20 is safe, that doesn't give you any information. That  
21 is not necessarily true.

22 MR. STROUP: Right, but you don't  
23 necessarily know that before you run the model.

24 MEMBER ABDEL-KHALIK: But if I know that  
25 the model is going to be non-conservative in the first

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1 place -- anyway, I think it is --

2 MR. JOGLAR: I still haven't evaluated a  
3 control room where running a zone model leads to non-  
4 abandonment conditions. If you evaluate even the  
5 bigger, multi-unit control rooms with the range of  
6 fires that are in the current guidance, in all  
7 cases --

8 MEMBER ABDEL-KHALIK: You need to abandon?

9 MR. JOGLAR: At some point in time, you  
10 will get to that conclusion unless you, then, provide  
11 some credit for smoke PIRT systems, and that has to be  
12 also incorporated in the analysis.

13 So, I am not disagreeing with your point.  
14 I am saying that, in practice, I haven't seen a case  
15 where you run a zone model with a range of fires that  
16 we postulate in control panels, even if they  
17 propagate, and it leads to a non-abandonment  
18 conclusion by itself.

19 MEMBER ABDEL-KHALIK: Right, but this is  
20 sort of a guide.

21 MR. JOGLAR: I understand.

22 MEMBER ABDEL-KHALIK: Right? And the same  
23 thing about fire Scenario 7. Presumably, you are  
24 doing this to get temperature histories for the  
25 structures, so that you can do a detailed structural

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1 analysis to find out whether the structures would fail  
2 or not. But if you are using a zone model, would you  
3 be able to get detailed spatial variations of  
4 temperature, not just the temporal variations of  
5 temperatures, that would allow you to do a detailed  
6 structural analysis?

7 MR. McGRATTAN: Point well-taken.  
8 Remember, I talked earlier about analyses that we  
9 threw out for the structural analysis example in the  
10 appendix? We threw out zFAST because we came to that  
11 same conclusion.

12 We had originally wanted to see, let's  
13 just simply use all the models and show them, good and  
14 bad. But, then, we decided that that assumption about  
15 the uniform upper layer temperature isn't appropriate  
16 when you are looking at a fire here and a structural  
17 member, you know, a couple of tens of meters away.

18 MEMBER ABDEL-KHALIK: Right.

19 MR. McGRATTAN: So, we are not saying that  
20 for every scenario that you have to use all of the  
21 models. Okay? That is not what the guidance says.

22 It typically says you start with the  
23 simple models, and if those simple models don't answer  
24 the questions or don't have the right physics, then  
25 you sort of move up the ladder of complexity.

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1 MEMBER ABDEL-KHALIK: Right, but I am sort  
2 of worried about words here.

3 MR. McGRATTAN: Okay.

4 MEMBER ABDEL-KHALIK: You know, where you  
5 say zone models are an appropriate tool to address  
6 this scenario, well, I do know that I am not going to  
7 be able to get spatial temperature gradients in a  
8 structure using a zone model. And if that is a  
9 critical boundary condition for all the structural  
10 analyses I would have to do to follow up this  
11 assessment, then I am not sure I used an appropriate  
12 tool to determine the temperature, the spatial  
13 temperature gradients.

14 MR. JOGLAR: I think that is a good point.  
15 Maybe the wording can be refined in terms of the  
16 capabilities, what the zone model would do versus the  
17 CFD. So that the user gets better guidance than just  
18 say this is appropriate.

19 MR. McGRATTAN: But are we talking about  
20 which model? Which scenario are we talking about now,  
21 5 or 7, in terms of the zone model?

22 MR. JOGLAR: I think 7. Seven, I think.

23 MR. McGRATTAN: Okay. I think 7? Okay,  
24 that might be a valid point.

25 MEMBER ABDEL-KHALIK: I think the same

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1 applies for 5 as well.

2 MR. McGRATTAN: Well, with 5, I would  
3 argue that a zone model is going to give you a decent  
4 vertical distribution temperature. In terms of  
5 habitability of the space --

6 MEMBER ABDEL-KHALIK: But temperature is  
7 not only the criteria.

8 MR. McGRATTAN: -- it doesn't say it, but  
9 I would add it, that it gives you a good vertical  
10 profile of temperature, and habitability is going to  
11 come down to, again, where that layer is at a  
12 particular time.

13 MR. JOGLAR: Yes, I think the results of  
14 the V&V in terms of what the zone model does for  
15 habitability in terms of hot gas layer shows that they  
16 are probably okay. I don't disagree that maybe we can  
17 improve the guidance in terms of saying how the CFD  
18 could be better or is better in terms of resolution.  
19 And that may be a case where it is necessary.

20 MEMBER ABDEL-KHALIK: But the abandonment  
21 criteria in Scenario 5 are not just based on  
22 temperature. So, okay, maybe the zone model would be  
23 able to tell you where that interface between the two  
24 zones will come --

25 MR. McGRATTAN: Right.

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1 MEMBER ABDEL-KHALIK: -- down to that.

2 MR. McGRATTAN: I'm sorry.

3 MEMBER ABDEL-KHALIK: But I don't think it  
4 would give you any indication as to the other criteria  
5 that would be consistent with the abandonment criteria  
6 that you had to apply.

7 MR. JOGLAR: Well, it does provide the  
8 visibility information and the heat flux  
9 information --

10 MR. McGRATTAN: Yes.

11 MR. JOGLAR: -- that it is part of the  
12 criteria. And you can correct me if I am wrong. It  
13 is probably the same models that we have in FDS --

14 MR. McGRATTAN: Right.

15 MR. JOGLAR: -- to come up with visibility  
16 information.

17 MR. McGRATTAN: Well, it is just the same  
18 model; it is not uniform, though.

19 MR. JOGLAR: Yes, it is not uniform, but  
20 it is the same --

21 MR. McGRATTAN: Similar assumptions, yes,  
22 about heat transfer and light transfer.

23 CHAIR STETKAR: By the way, in practice,  
24 like I said, I am not a fire modeler, but for main  
25 control room abandonment, if I am doing a real fire

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1 analysis, there are a lot of other things that I need  
2 to consider, like, for example, if the fire is burning  
3 instrumentation and controls, so I don't know what the  
4 heck is going on in the plant, all of this stuff about  
5 smoke layer and temperatures is sort of irrelevant.

6 MR. JOGLAR: Correct.

7 CHAIR STETKAR: I realize this is a fire-  
8 modeling tool, but --

9 MR. JOGLAR: In the PRA, we address both  
10 cases, that you have to leave the control room due to  
11 habitability or due to operability, right. You may  
12 have a small enough fire in a cabinet that is so  
13 important that you have to do things outside the  
14 control room.

15 CHAIR STETKAR: Okay.

16 MR. JOGLAR: And the peer reviews look for  
17 that, and we try to make sure that they are  
18 appropriately modeling the fire PRA.

19 CHAIR STETKAR: Yes, it is not directly  
20 relevant to this particular application.

21 MR. JOGLAR: Sure.

22 CHAIR STETKAR: It is just sensitivity  
23 that somebody who is doing a real analysis -- just  
24 because it says you don't have to abandon the control  
25 room for 37.62 minutes for this thing doesn't mean

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1 that the people are actually going to stay there that  
2 long.

3 MR. JOGLAR: Yes. So, we actually have  
4 like, you know, event trees that said you have to  
5 abandon because of this reason, because of the other  
6 reason, and what happens then.

7 This is probably an example similar to  
8 what I just covered, where we would provide guidance  
9 on how to deal with sprinkler activation, smoke  
10 detection, features that are near the flames or in the  
11 fire plume. And it goes step-by-step and provides  
12 qualitative guidance that can help. You know, you are  
13 managing a job like this. Are you the fire protection  
14 engineer that is subcontracting this work? It is not  
15 necessarily to somebody that is actually doing the  
16 model, but it gives a big-picture information of what  
17 is important, what kind of plant data is necessary,  
18 what is the outcome that is expected.

19 This is where we try to bring in, that I  
20 mentioned those terms that we were discussing earlier.  
21 Although that is part of our Chapter 4, we thought now  
22 that we have the sketches, let's include it in this  
23 part of the presentation.

24 And what we are trying to highlight in  
25 this slide is some of the parameters that you can see

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1 in red and with arrows that are included in those  
2 dimensionist terms, like the size of the room, the  
3 height of the room, the heights above the fire, the  
4 radial distances, the fire diameter. These are the  
5 kind of parameters -- as you can see, we are trying to  
6 apply those V&V resources, which are limited by the  
7 experiments we have, to all these large numbers of  
8 configurations of scenarios that we have in the  
9 plants. And that is what this slide is trying to  
10 highlight by pointing out these parameters. Okay?  
11 You can see the diameter for the size of the fire, the  
12 radial distances, et cetera.

13 We generally give two types of guidance on  
14 what to do if we are outside the validation range.  
15 And we have had this discussion. I guess we are all  
16 in agreement that it is relatively short versus the  
17 guidance we provide for a problem that is real.

18 We try to solve that in our examples. We  
19 didn't, conveniently, pick examples that everything  
20 fit. We tried to just go to realistic examples and  
21 see what we do.

22 And the guidance we are providing is in  
23 terms of sensitivity analysis or referencing other  
24 validation studies. Of course, this is followed up,  
25 like what Mark was saying, by more research in terms

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1 of V&V. So that we can, hopefully, extend those  
2 ranges.

3 Also, our V&V is pointing us to areas  
4 where modeling improvements are needed. And  
5 hopefully, in the future we can deal with that.

6 So, these are the two points where we  
7 offer guidance in terms of what to do if you fall out.  
8 At the very least, we are recognizing the problem is  
9 a real problem. People are going to face it, no  
10 question about it, and this is a step in the direction  
11 of, if you are there, you have to do more work,  
12 justify what you are doing.

13 Sometimes in the fire PRA you have tools  
14 outside fire modeling to say, "I'm conservative  
15 because...", and that can probably be okay. And  
16 sometimes you have to be conservative in your fire  
17 modeling to make the point. Sometimes you can --

18 MEMBER BLEY: Your first item, the  
19 sensitivity analysis to do a calculation that is more  
20 severe, yet in the range --

21 MR. JOGLAR: Yes.

22 MEMBER BLEY: -- worries me a bit. And I  
23 have tried this in a lot of places to see what you  
24 get. But deciding if you are more severe, depending  
25 on why you fall outside of the range, it might be

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1 pretty hard to know for sure you are more severe.

2 MR. JOGLAR: Well, in my experience,  
3 sometimes it is not. Sometimes the fire sizes and all  
4 of that falls into the range, and all is outside; the  
5 room is a bit bigger. And all it takes is reshaping  
6 the room to a smaller one.

7 So, if it is really more difficult and we  
8 cannot justify our variations, probably it is not a  
9 good idea to go there. But we have found cases where  
10 it is just a matter of shifting the width of a room.

11 MEMBER BLEY: Yes. No, that makes sense  
12 to me. But the other side of it is -- and to tell you  
13 the truth, I don't remember how careful the guidance  
14 is in this section -- but I hope you have made it  
15 clear what kind of especially simple cases make it  
16 easy to decide if you are more severe or when you  
17 could get into trouble because you have multiple  
18 variables involved, and it is real hard to decide.

19 MR. JOGLAR: Yes, I think this is a good  
20 comment, and we should certainly go and check the  
21 guidance to make sure --

22 MEMBER BLEY: And I'm not sure. It wasn't  
23 until I looked at your slide that I said, gee, I'm not  
24 so sure about that.

25 MR. JOGLAR: No, but it is probably a good

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1 idea to check that, when we say makes it much more  
2 severe, there is enough there to make it clear what  
3 "more severe" means.

4 MEMBER SCHULTZ: Yes, and to make sure  
5 that you are not providing too much latitude, because  
6 that is a very simple statement which could be  
7 misinterpreted to provide a lot of latitude into which  
8 variables might be changed. And it might become very  
9 difficult to determine the conservatism.

10 MR. JOGLAR: If I recall correctly, we  
11 went through the different parameters and kind of  
12 suggested which of them should make things more  
13 severe. We probably will make sure, based on this  
14 comment --

15 MEMBER BLEY: I mean, if you just have  
16 one, then it is pretty easy to deal with. If you have  
17 two or more than two, it could get pretty tricky, I  
18 suspect. And I don't know you warn folks about that.  
19 I don't remember that, anyway.

20 MR. McGRATTAN: Right. And while it is  
21 ultimately the reviewing authority who decides whether  
22 or not it is, indeed, more severe --

23 MEMBER BLEY: Eventually, I guess we get  
24 to a reviewer who would be real good at that, but I  
25 don't know sure along the way we do.

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1 MR. McGRATTAN: Well, I mean, we are  
2 giving advice to the users, "Here are strategies that  
3 you can use if you are outside of this range."

4 I think there is a good example on the  
5 next slide. Do you still have that? I mean, I think  
6 this is a very typical way that this technique is  
7 used.

8 MR. JOGLAR: Yes, where the ceiling height  
9 ratio to the corridor -- the corridor length to  
10 ceiling height ratio is outside the range, and we,  
11 basically, reshape. Okay?

12 I think it is a good common rule.  
13 Certainly, review of the guidance, we have to make  
14 sure it is clear, and at least we caution people, when  
15 you start varying more than one parameter, where the  
16 analysis is going to go. It doesn't necessarily go to  
17 a more severe --

18 MEMBER BLEY: You guys have seen the cases  
19 where you have fallen outside the range; I haven't.  
20 So, I don't know if it is real likely, if being out of  
21 range in multiple ways is likely.

22 MR. JOGLAR: In my experience, when we  
23 have applied it, it is very clear, just one of the  
24 parameters, and those are --

25 MEMBER BLEY: Well, it is always like

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1 that; it is no problem -- yet.

2 MR. JOGLAR: Yes. I understand.

3 Okay. So, as we covered, we tried to give  
4 qualitative guidance in terms of what is the objective  
5 of this scenario, the modeling strategy, and  
6 recommended models to use. And most importantly, we  
7 sent people to the detailed examples of where they can  
8 find actual quantitative examples of this.

9 This is based, focused on the user, and we  
10 recognize that in the industry the users are not  
11 experienced consultants that do this for a living.  
12 The users may be managers, plant personnel, that just  
13 need to have an idea to manage these kind of problems.  
14 And so, we include a Chapter 3 to provide such a  
15 guidance, fully aware that the guide is then heavy on  
16 actual quantitative examples.

17 With that, we can go to Chapter 4.

18 CHAIR STETKAR: Just before we switch  
19 gears here, anybody have any more questions on 3?

20 (No response.)

21 Now you can switch gears.

22 MR. McGRATTAN: So, my background, I am  
23 Kevin McGrattan from the National Institute of  
24 Standards and Technology. My background is in  
25 mathematics and model development.

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1 I have been working on CFD models probably  
2 for my whole career at NIST. That has brought me into  
3 collaboration with the NRC.

4 I should mention that this Model Users'  
5 Guide, there is an earlier version of it that was  
6 produced by EPRI in, I believe, 2001. At that time,  
7 CFD wasn't even on the table. So, that just gives you  
8 an idea of how rapidly we are coming along in fire  
9 protection engineering. I know that CFD is used  
10 extensively in a wide range of engineering fields, but  
11 it is somewhat late in the fire protection engineering  
12 community.

13 These were just duplicate slides that  
14 Francisco presented. I want to talk about uncertainty  
15 in Chapter 4.

16 NUREG-1855 actually describes three major  
17 types of uncertainty. And a lot of times when we talk  
18 about fire model uncertainty, we get these terms  
19 confused. A lot of people think it is what happens  
20 when I change the heat release rate; what happens when  
21 I do this, and what happens when I do that.

22 That would be parameter uncertainty.  
23 Parameter uncertainty is addressed in different ways,  
24 depending on the applications. What we wanted to  
25 focus on our attention in this guide was the model

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1 uncertainty. That is, the uncertainty inherent in the  
2 model itself.

3 If you have a set of input parameters that  
4 are, say, perfect, not that they ever are, but let's  
5 just say, for the sake of argument, we have perfect  
6 input parameters. Just what is that uncertainty that  
7 comes from the model itself?

8 So, in my presentation we are focusing on  
9 the model uncertainty. I will talk at the end how we  
10 might also address things like parameter uncertainty.

11 MEMBER BLEY: Kevin?

12 MR. McGRATTAN: Yes?

13 MEMBER BLEY: Let me interrupt you here  
14 with a few questions because your slides aren't  
15 completely structured the way the report is, and I  
16 have some things I want to ask about.

17 MR. McGRATTAN: Right.

18 MEMBER BLEY: So, I will give you a heads-  
19 up ahead of time on these, and I think they will come  
20 up later.

21 We mention 1855 upfront, but, then, we  
22 don't link to it at all after that in the section, and  
23 treat things quite a bit differently. Let me talk  
24 about the three areas and those kind of things.

25 Model uncertainty, you've got about two-

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1 thirds of the section on that. Parameter uncertainty  
2 is almost a third. I don't think you have any slides  
3 on that. And there were some things in there that I  
4 really want to get into and talk about.

5 My general comments on the model  
6 uncertainty, from my point of view, are that much of  
7 what you have done -- and it is very nice; I like it  
8 -- but it hinges on the two assumptions you talk about  
9 back where you develop the statistics. And I don't  
10 think I saw these in the slides.

11 One is that the experimental measurements  
12 are unbiased and are normally distributed. That is  
13 probably reasonable. You don't justify it a whole  
14 lot, but it seems to me that is pretty reasonable.

15 Model error is assumed to be normally  
16 distributed. You don't give much justification of  
17 that. From the examples that you show in the report,  
18 for the range where everything falls within the  
19 validation study, even if that one is not too solid,  
20 I think it all hangs together and it is probably very  
21 reasonable.

22 For the other two cases, I don't know  
23 quite --

24 MR. McGRATTAN: Right. Yes.

25 MEMBER BLEY: -- how one deals with that.

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1 And then, I don't think there is much help for the  
2 person here, unless you can find another validation  
3 study to hang to that works for your case.

4 MR. McGRATTAN: The issue of normality  
5 came up at the hearings for 1824.

6 MEMBER BLEY: Okay.

7 MR. McGRATTAN: At that time, we were  
8 considering further quantifying the results of that  
9 study, but we didn't feel that we had solid  
10 justification for making this assumption of normality.  
11 Since then, we have tested the datasets from 1824 for  
12 normality, and we found that most of them, about 75  
13 percent of these datasets, were normally distributed.  
14 The exceptions were cases where the number of data  
15 points that we had were literally half a dozen, for  
16 example, for which we couldn't really fit any  
17 distribution.

18 MEMBER BLEY: Anything. Sure.

19 MR. McGRATTAN: So, a lot of our analysis  
20 and the simplifications we make are based on this  
21 assumption of normality because it does great simplify  
22 the development and application of this uncertainty  
23 methodology.

24 MEMBER BLEY: Okay. That's good. I want  
25 to put something else on the table that I don't think

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1 affects what you have done too much, but I just want  
2 to put it out there in case you want to say something  
3 about it.

4 That is separate from these three types of  
5 uncertainties -- well, not separate from them -- not  
6 catalogued among them, you talk about the experimental  
7 uncertainty. I think the whole derivation kind of  
8 hinges on the idea that the experimental uncertainty  
9 is really an aleatory randomness uncertainty due to  
10 measurement. And if you were always measuring the  
11 same thing, I think the case is real strong that that  
12 is normal and that everything is reasonable.

13 MR. McGRATTAN: Yes.

14 MEMBER BLEY: I think you can't really  
15 show, since every case is a little different, that  
16 that separation is clean. So, the stuff that gets  
17 catalogued as experimental uncertainty gets catalogued  
18 because that is what it would be if, in fact, the  
19 assumptions about it held true everywhere. So, there  
20 is probably some mixing. So, it is probably not  
21 purely epistemic, I mean aleatory anymore. I don't  
22 think that affects much, but it just seems that is a  
23 little odd spot here.

24 All three of the things that you are  
25 trying to address here you describe as epistemic,

1       except the experimental, which would be aleatory, and  
2       you cover that. So, I think those are all pretty  
3       good, but not quite catalogued right. So, that  
4       doesn't really affect the guidance here.

5               On the like second or third page, you have  
6       a slide coming up where you show one of the  
7       experimental results. Unfortunately, it is not the  
8       one that is in the paper. The one that is in the  
9       paper made me want to ask a question.

10              We talk about that these have been  
11       validated and that, outside of the range of  
12       validation, it is based on the parameters --

13              MR. McGRATTAN: Right.

14              MEMBER BLEY: -- that didn't fit within  
15       that experiment. But if I look at the one that is in  
16       the report, for temperatures below about 300 degrees,  
17       everything really looks nice. For beyond there, where  
18       the data are a bit sparse, half to two-thirds of the  
19       data points are outside of the 95th percentile, which  
20       means the assumptions about the distribution can't be  
21       right out there.

22              MR. McGRATTAN: Right.

23              MEMBER BLEY: So, all the calculations  
24       based on the sigma Es and the sigma Ms, when you get  
25       to temperatures out in that range, become a little

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1 suspect. Because over half, you know, it is not 5  
2 percent, but 50 percent or more are outside.

3 MR. McGRATTAN: Right.

4 MEMBER BLEY: So, I get a little concerned  
5 that the very nice, rigorous uncertainty we calculate  
6 when the temperatures get above, for this case, get  
7 above 300, don't mean quite what it looks like they  
8 are saying they mean. So, we are missing some of the  
9 uncertainty that is there --

10 MR. McGRATTAN: Right.

11 MEMBER BLEY: -- because of that  
12 sparseness of data or not quite fitting, when you get  
13 out in those other regimes. And I don't think we are  
14 characterizing the uncertainty out in that area right  
15 because of that.

16 MR. McGRATTAN: Right. We debated this  
17 quite a lot because our original goal was that, for a  
18 given model and a given output quantity, we want to  
19 make it relatively simple to do this uncertainty  
20 analysis.

21 But you're right. I mean, you could take  
22 these scatter plots and you will find complexity in  
23 them. But if we got to the point where, you know, if  
24 you said, well, if you are above this temperature,  
25 then use these numbers; if you are below this, use

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1 these numbers, it became very difficult to put  
2 together something that was usable.

3 And our goal here is to come up with  
4 something that is usable because a lot of the work  
5 that has been done prior to this, all the papers that  
6 I have read, the analysis of the uncertainty becomes  
7 so difficult that, in my opinion, it is simply being  
8 ignored by the analysts. What we want to try to do --  
9 I am not saying your points are invalid; I am just  
10 saying that we had to make simplifications in order to  
11 make this workable.

12 MEMBER BLEY: I understand.

13 MR. McGRATTAN: Yes.

14 MEMBER BLEY: My beginning comment,  
15 though, was that we don't use much of what is in 1855  
16 beyond this basic three-element categorization. It is  
17 kind of getting that there are other things one can  
18 do. And I know you want it to be explicit and  
19 quantified and easy to do.

20 MR. McGRATTAN: Yes.

21 MEMBER BLEY: On the other hand, if you  
22 get into regimes where the uncertainty is being  
23 mischaracterized, helping people learn how to apply  
24 expert judgment in those regions, aware of all the  
25 evidence underneath it, to give them more honest

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1 representation of that uncertainty where the risks  
2 might lie out there, it seems to me like it ought to  
3 be there.

4 And I think some of that same kind of  
5 advice could be applied to the cases where you are  
6 outside the range of validation as well. So, you have  
7 got a lot of information. Now you hit a point where  
8 things don't quite fit right.

9 MR. McGRATTAN: Right.

10 MEMBER BLEY: What do you do? You can  
11 say, "Well, we can't do anything." Or you can do  
12 something simple that you know is underestimating the  
13 uncertainty, which isn't what we want to do. Or you  
14 can use all of that information and take a step  
15 further and apply some judgment to account for that,  
16 and try to do the best job you can, and maybe  
17 eventually be able to do it more rigorously and  
18 easily, too.

19 And I'm sorry, I cut you off three times,  
20 but I wanted to get all that out.

21 MR. JOGLAR: No, I apologize. This  
22 doesn't address your fundamental point, but, as a  
23 practical comment, I am not aware of very many  
24 applications in the nuclear industry fire modeling  
25 work where things that have 300-degrees are an issue.

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1                   MEMBER BLEY: Well, your examples had  
2 some, right?

3                   (Laughter.)

4                   MR. JOGLAR: All the cable damage we  
5 analyzed are in the range of 300 or less.

6                   MEMBER BLEY: And that's great. But the  
7 example you showed me --

8                   MEMBER SHACK: Many of your models are  
9 going to be used outside their range of validation,  
10 which is what we are seeing right here.

11                   MEMBER BLEY: And if you are talking  
12 structural stuff, then above 300 is going to be  
13 important.

14                   MR. JOGLAR: Yes, that is the only one,  
15 but most of the cable damage is always --

16                   MEMBER BLEY: But, I don't see, when I  
17 read this, nothing here tells me any of that, and  
18 nothing tells me where I am getting fuzzy. And even  
19 though I am within the range of validation, I have  
20 got, on the one example that is here, some areas that  
21 are questionable where we are probably understating  
22 the uncertainty. Instead of going like this, it  
23 probably is doing something like that.

24                   MR. McGRATTAN: Right, and it often comes  
25 down to the judgment of the reviewer.

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1 MEMBER BLEY: But the reviewer is not  
2 getting any advice here, either, on these things.

3 MR. McGRATTAN: Well --

4 MEMBER BLEY: These are kind of subtle  
5 points unless you do this for a living and study this  
6 sort of thing.

7 MEMBER SCHULTZ: Then, Francisco, the  
8 rationale that you provided is extremely valuable.

9 MEMBER BLEY: Very valuable, and one that  
10 doesn't apply. And that would be valuable for all of  
11 these cases where things don't quite fit right.

12 MR. JOGLAR: Yes, what I was going to  
13 comment -- and I thank you for pointing it out -- is  
14 that maybe our guide may use a number of bullets  
15 saying these are the practical ranges for where this  
16 is applied, since this is an applications guide. It  
17 doesn't solve the fundamental problem that we see  
18 scattered outside 300 degrees. But to the extent that  
19 you are using it for typical applications of cable  
20 damage, this is --

21 MEMBER BLEY: Now the one you picked to  
22 show us on the slides is a lot less challenging out in  
23 those regimes.

24 (Laughter.)

25 MR. McGRATTAN: Let me point out some of

1 the difficulties we face.

2 MEMBER BLEY: It does drift, but --

3 MR. McGRATTAN: So, if you look at this  
4 plot, it is a comparison of measurements versus  
5 predictions for a particular model or a particular  
6 quantity.

7 MEMBER BLEY: Right.

8 MR. McGRATTAN: And the colors represent  
9 temperatures of the floor, walls, ceiling. So, we had  
10 to decide, do we want to develop statistics for each  
11 one of these? Because it clearly looks like the model  
12 in this case is underpredicting the ceiling  
13 temperatures, overpredicting the short-wall  
14 temperatures.

15 MEMBER BLEY: That's true, it does.

16 MR. McGRATTAN: Okay? So, there's still  
17 going to be judgment by the reviewer who --

18 MEMBER BLEY: But at least they are all  
19 hanging within these bounds.

20 MR. McGRATTAN: -- wants to look at these  
21 plots and say, "You know what? You are using this  
22 model to predict the ceiling temperatures in this  
23 compartment. I know that you are using the bias and  
24 standard deviation that are recommended in general,  
25 but we are not comfortable with that. Rerun the

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1 numbers for those green dots."

2 MEMBER BLEY: Yes, you get a new bias.

3 MR. McGRATTAN: You get a new bias and you  
4 get a new standard deviation.

5 MEMBER BLEY: And on the one that is in  
6 the book, you get different standard deviations out in  
7 another range.

8 MR. McGRATTAN: Right, right.

9 Even after 1824, when we came up with this  
10 color chart -- and I will describe why the color chart  
11 didn't last -- but, nevertheless, there was this  
12 yellow color that we wanted to use to say, in  
13 situations where you are using this model and we judge  
14 it to be yellow, look more closely at the specifics of  
15 the validation study. And we are talking to the  
16 reviewer, say NRR.

17 MEMBER BLEY: Okay.

18 MR. McGRATTAN: Look closely at it because  
19 sometimes it is very difficult to succinctly describe  
20 the outcome of half a dozen experiments. We have  
21 tried to keep it simple but at the same time leave  
22 open the possibility of further analysis. That is why  
23 we make the plots the way we do, because I think in  
24 this case you can look at these colors and see where  
25 the model is underpredicting or where it is

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1 overpredicting.

2 So, I see your point, but it is a  
3 challenge to still make this tractable for the user.

4 MEMBER BLEY: But to do it rigorously gets  
5 very challenging, to provide some guidance what to do  
6 when you get into these places. And I like the  
7 colored plots. I think that is very helpful.

8 That not only helps the person trying to  
9 do it, but they can understand. They can look at this  
10 and say, well, why in the heck would I be doing it  
11 this way? That helps them understand what they ought  
12 to do to correct the basic advice.

13 MR. McGRATTAN: Right, right.

14 MEMBER BLEY: But it helps the reviewers,  
15 too. And I think sending the reviewers to go review  
16 1824 would be grand, but that is a lot of stuff in  
17 there.

18 (Laughter.)

19 I wasn't here when we reviewed it the last  
20 time, but I got into it a bit here. It is all nice  
21 work, but I think just some things like this to give  
22 advice what to do when things aren't right.

23 MR. McGRATTAN: Okay.

24 MEMBER BLEY: And, yes, maybe the  
25 reviewers catch it. But why not help people out a

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1 little bit?

2 MR. McGRATTAN: Okay.

3 MEMBER BLEY: And avoid some things that  
4 are just not quite right.

5 MEMBER ABDEL-KHALIK: I have a related  
6 question. Presumably, each point on this graph  
7 represents an experiment.

8 MR. McGRATTAN: A single measurement  
9 within a particular experiment.

10 MEMBER ABDEL-KHALIK: Right. But it  
11 doesn't necessarily mean that all of these come from  
12 the same test facility, do they, or the same series of  
13 experiments?

14 MR. McGRATTAN: It doesn't necessarily  
15 always. In this case, it does. All of these points  
16 came from a single experiment.

17 MR. JOGLAR: But it, in general, is not.  
18 The other plots, you are correct in saying that in  
19 most cases they don't, right?

20 MR. McGRATTAN: As far as different  
21 experiments.

22 MEMBER ABDEL-KHALIK: So, how do you come  
23 up with the experimental value for sigma? Or how do  
24 you decide on bias, if the experiments are internally  
25 inconsistent? In other words, one set of

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1 experiments --

2 MR. McGRATTAN: For the experimental  
3 uncertainty, we --

4 MEMBER ABDEL-KHALIK: No, no. Okay. You  
5 have experiments coming from Sandia, experiments  
6 coming from another test organization --

7 MR. McGRATTAN: Right.

8 MEMBER ABDEL-KHALIK: -- NIST. And if I  
9 plot them without distinguishing between the data  
10 coming from here or there, I see this scatter plot.

11 MR. McGRATTAN: Yes.

12 MEMBER ABDEL-KHALIK: But if I were to  
13 distinguish them by facility, I see that the Sandia  
14 data are biased in one direction versus the NIST data.  
15 Then, how would I determine the overall bias of the  
16 model if the data itself is internally biased?

17 MR. McGRATTAN: Well, we know that  
18 different test facilities are going to have biases,  
19 just the way that they make their measurements, their  
20 hood systems, and so forth. We have no way of  
21 quantifying that. We have no way to say that Sandia  
22 typically measures temperatures too high and NIST  
23 measures too low. We have to assume that the  
24 experimental measurements are unbiased.

25 MR. JOGLAR: And what gives us some

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1 comfort --

2 MR. McGRATTAN: We have no recourse. I  
3 have no way to distinguish between the NIST facilities  
4 and Sandia facilities.

5 MR. JOGLAR: What gives us some comfort is  
6 that we do select experiments that are of quality,  
7 meaning that we can track the experimental setups.  
8 They have reports. We have enough information to tell  
9 us what equipment was used, how the measurements were  
10 made, which in fires sometimes those we don't have.  
11 Some person just hooked up a thermocouple, made a  
12 measurement, and this is the experiment.

13 These, for lack of a better word, have  
14 some pedigree, and we can get a hold of the  
15 experimental reports, and all the equipment and  
16 everything is referenced. So, to the extent that that  
17 provides some kind of --

18 MEMBER ABDEL-KHALIK: So, as far as you  
19 are concerned, in doing this comparison, you are  
20 essentially assuming that all of these experiments  
21 have the same pedigree, as if they are all coming from  
22 the same facility?

23 MR. McGRATTAN: We assume they are all  
24 unbiased, but, based on the type of measurement that  
25 was made, whether the heat release rate was determined

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1 through oxygen consumption, calorimetry, or mass loss,  
2 we assign greater or less uncertainty to those  
3 measurements. And that uncertainty is based on  
4 estimates made by the testing labs themselves, who  
5 often give rough estimates of the uncertainty in their  
6 measurements.

7 MEMBER BLEY: The main problem I think  
8 that accrues from that is you get some mixing of the  
9 different uncertainties and you get a mix of epistemic  
10 with systematic uncertainty. I think it is probably  
11 not the biggest deal. In looking at it, that is my  
12 suspicion.

13 MR. McGRATTAN: Right, right.

14 Okay. So, it seems like we all understand  
15 the basic idea behind the uncertainty analysis. I  
16 just want to point out again, after 1824, we decided  
17 to qualitatively assign a color rating to the  
18 different models and predicting the different  
19 quantities. Green, yellow, and we were supposed to  
20 use red, but red never made it on the chart.

21 Nevertheless, we have decided to get rid  
22 of this chart. It actually came as a recommendation  
23 of the ACRS back when you reviewed 1824: color  
24 designations provide no quantitative estimate of the  
25 intrinsic uncertainty.

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1                   This was a big sticking point then. I  
2 remember being either in this room or the next, and we  
3 discussed whether or not we would have a better way to  
4 quantify the data. Our solution was to develop this  
5 chart.

6                   MEMBER BLEY: Go back. Go back one, two.  
7 Two. No, one more, to your colors.

8                   MR. McGRATTAN: Yes.

9                   MEMBER BLEY: I certainly agree with this  
10 statement that was made before I was here.

11                   MR. McGRATTAN: Okay.

12                   MEMBER BLEY: It wasn't quantitative, but  
13 maybe there is some qualitative utility here. I mean,  
14 you threw this all out. But I am not sure about that.

15                   MR. JOGLAR: Well, it is very useful.

16                   (Laughter.)

17                   MEMBER BLEY: Yes, that is what I am  
18 saying I am not sure that throwing it away is  
19 altogether the right thing. But having both --

20                   MR. McGRATTAN: But the numbers that we  
21 developed --

22                   MEMBER BLEY: Yes.

23                   MR. McGRATTAN: -- instead should  
24 correspond to the green and yellow markings. However,  
25 what we found is, when we actually crunched those

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1 numbers, what we assigned green and what we assigned  
2 yellow wasn't necessarily consistently --

3 MEMBER BLEY: So, these were intended to  
4 be surrogate quantification?

5 MR. McGRATTAN: They were.

6 MEMBER BLEY: Okay. That is what I meant  
7 to ask you.

8 MR. McGRATTAN: Yes.

9 MEMBER BLEY: Okay.

10 MR. McGRATTAN: And also --

11 MEMBER BLEY: So, keeping them is not a  
12 good thing.

13 MR. McGRATTAN: Right, and everybody has  
14 a different interpretation of yellow, right? When you  
15 are driving down the road and you see a yellow light,  
16 some people think it means slow down.

17 MEMBER BLEY: It depends on where you grew  
18 up.

19 (Laughter.)

20 MR. McGRATTAN: Some people think it means  
21 speed up.

22 MEMBER BLEY: That's right.

23 MR. JOGLAR: But, nevertheless, we  
24 intended them to be useful. And in practice, what we  
25 intended was, if it is green, the model is as good as

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1 it gets.

2 MEMBER BLEY: Okay, but now we have  
3 numbers.

4 MR. JOGLAR: Yes.

5 MEMBER BLEY: And this was intended to be  
6 a surrogate.

7 MR. McGRATTAN: Yes, yes.

8 MEMBER SCHULTZ: So, that is your  
9 interpretation of what the colors, and someone else  
10 might have a different interpretation of what the  
11 colors --

12 MR. McGRATTAN: What they originally meant  
13 was, when we saw the points, more or less -- more or  
14 less, and it is very rough -- sort of falling within  
15 the experimental uncertainty, what we said, the model  
16 is as good as it can be. That is what Francisco means  
17 by that, because the model cannot be any better than  
18 the data it is compared against. So, we would give  
19 this model and this quantity the green rating.

20 But, then, we got to the point where,  
21 obviously, in many cases the data is scattering  
22 outside of -- like I had a plot here. Those black  
23 lines here represent the experimental uncertainty,  
24 and, clearly, the data is scattering outside of the  
25 experimental uncertainty.

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1           So, we decided, well, let's draw another  
2 set of lines, quantified better, the model  
3 uncertainty, and then summarize all of that in this  
4 chart. So that, for any given model and any given  
5 quantity that we want to predict, there is a bias  
6 factor, delta, where one means on average the model  
7 predicts the experimental measurement. And then,  
8 there is a standard deviation about that average.

9           And again, if you look at these numbers  
10 carefully, they roughly correspond to the green and  
11 yellow colors. But we thought it was better to  
12 provide this quantification. Plus, with this, you can  
13 actually do something with it; whereas, with the  
14 yellow and green you can't do anything with it.

15           At least now, if we make the assumption of  
16 normality and we are asked the question, you know, if  
17 my cables fail at 350, my model predicts 300, what is  
18 the probability that, given the uncertainty in the  
19 model, that I still will fail the cables?

20           MEMBER BLEY: And if you have uncertainty  
21 on when it fails, you can cover that case just as  
22 well.

23           MR. McGRATTAN: Right.

24           MR. JOGLAR: So, in a fire PRA  
25 application, now there is a tool to address cases

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1 where your model predicts something very close to the  
2 damage.

3 MEMBER BLEY: And your example was real  
4 nice. When they were very close, you had almost a  
5 50/50 chance of being failed, which is --

6 MR. JOGLAR: Yes.

7 MEMBER BLEY: -- different from the old,  
8 if I come just below, I'm good, you know.

9 (Laughter.)

10 MR. McGRATTAN: Right, right.

11 MEMBER SCHULTZ: This is a good summary as  
12 to why the statement was originally made by the ACRS  
13 that the colors did not provide what could be  
14 provided. And you are coming to the point where you  
15 are giving that information and it is available to be  
16 used.

17 MR. McGRATTAN: Right, right. I mean, we  
18 refer this amongst ourselves as "the George question"  
19 because it was George who asked, if CFAST predicts  
20 350, 350 plus or minus what? And we didn't have a  
21 good answer at that point. We had our colors, but we  
22 didn't have a good way of quantifying the plus or  
23 minus.

24 MEMBER BLEY: I find it interesting that,  
25 even the models I suspect that are intended to be

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1 realistic mostly overpredict. There's only a few  
2 cases where you underpredict on your last chart.

3 MR. McGRATTAN: Right.

4 MR. JOGLAR: It is why I said there is  
5 some utility in the colors. Because if you see some  
6 of the yellow-plus, our results show everything is  
7 overpredicted. So, we said, in practice, if you do a  
8 yellow-plus calculation and you show no damage, you  
9 should have the comfort that that is the answer. So,  
10 there was some practicality in terms of the colors, as  
11 we defined them.

12 MEMBER BLEY: Okay.

13 MR. McGRATTAN: Okay. I don't need to --

14 MEMBER ABDEL-KHALIK: Back to the table  
15 with the bias factor and the standard deviations --

16 MR. McGRATTAN: Yes.

17 MEMBER ABDEL-KHALIK: -- I am particularly  
18 sort of interested in the two middle columns that  
19 pertain to the zone models.

20 MR. McGRATTAN: Uh-hum.

21 MEMBER ABDEL-KHALIK: Again, given the  
22 point that was raised earlier about the fact that  
23 these models do homogenize what was going on, are  
24 these local parameters or are these average  
25 parameters?

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1 MR. McGRATTAN: Some are local; some are  
2 average. For example, the HGL temperature rise and  
3 depth, those are integrated quantities where we take  
4 many thermocouple measurements in the upper layer of  
5 a compartment, average them together, and compare that  
6 with the zone model calculation. So, that would tend  
7 to make the zone model look more accurate.

8 MEMBER ABDEL-KHALIK: Right, because you  
9 are sort of averaging --

10 MR. McGRATTAN: You are averaging things  
11 out.

12 MEMBER ABDEL-KHALIK: Right, right. How  
13 about the heat flux?

14 MR. McGRATTAN: Whereas, heat  
15 concentration, smoke concentration, heat flux, those  
16 are all local.

17 MEMBER ABDEL-KHALIK: Right.

18 MR. McGRATTAN: And in there, you are  
19 going to see a lot more scatter. Because if you have  
20 a point on the wall in the upper layer, and you  
21 surround that point with hot black smoke, an average  
22 temperature is not going to give you an accurate heat  
23 flux.

24 MEMBER ABDEL-KHALIK: Right. So, that was  
25 really the underlying reason for my question. What is

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1 the utility of making that comparison for a local  
2 measurement vis-a-vis a value predicted by a  
3 homogenization model?

4 MR. McGRATTAN: I think that the only  
5 answer to that is historical precedent. And that is  
6 these models, in order to compare all of the models  
7 together, the hand calculations, the zone models, and  
8 the CFD, we decided that that is what we would  
9 compare.

10 But you are right, the point is well-  
11 taken. If you actually say, predict this temperature  
12 at this point with a zone model, you are going to have  
13 a different level of accuracy.

14 MEMBER ABDEL-KHALIK: Right, depending on  
15 where the experimentalist decides to put --

16 MR. McGRATTAN: Right.

17 MEMBER ABDEL-KHALIK: -- the instrument.

18 MR. McGRATTAN: Right. I think, on  
19 average, if you assume that you have the instruments  
20 randomly distributed, on average, it is going to work,  
21 but there is going to be more scatter. The sigma M is  
22 going to be larger.

23 Okay. Rick, do you want to make a  
24 comment?

25 MR. PEACOCK: Yes, if I can. I think part

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1 of it is that the concept --

2 MR. McGRATTAN: Rick, have you introduced  
3 yourself before?

4 MR. PEACOCK: I did before. I am Rick  
5 Peacock from NIST. I am largely CFAST, but other  
6 things, too.

7 The concept of a zone model, I agree with  
8 you, the upper layer is a representative temperature  
9 of the heat capacity, the heat content in that layer.  
10 But not everything the model does is a homogenized  
11 calculation.

12 For example, heat flux to a point on the  
13 wall, which is how we do the target heat flux and/or  
14 wall heat flux, is a calculation of the heat flux to  
15 that point from the fire, from the layer, from other  
16 hot surfaces. It is a much more granular calculation  
17 than the CFD model, but it is not a totally  
18 homogenized calculation.

19 MEMBER ABDEL-KHALIK: I understand, but  
20 what goes into it --

21 MR. PEACOCK: Some things are --

22 MEMBER ABDEL-KHALIK: -- are homogenized  
23 parameters.

24 MR. PEACOCK: Some of them are and some of  
25 them aren't, yes, you're right.

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1 MEMBER ABDEL-KHALIK: So, if you are  
2 doing --

3 MR. PEACOCK: So, the extent to which the  
4 upper layer temperature is important to that  
5 calculation is going to affect, and that is what you  
6 are seeing in the larger uncertainties.

7 MEMBER ABDEL-KHALIK: Right.

8 MR. McGRATTAN: I use this slide to point  
9 out the fact that the calculation of these  
10 probabilities is relatively simple. This idea came to  
11 us because Francisco was describing what is involved  
12 in a typical fire PRA.

13 It is not a couple of calculations. It is  
14 potentially hundreds or thousands of calculations that  
15 are done. And we need a way of characterizing the  
16 results.

17 In the Users' Guide, here is what we  
18 propose as a way of presenting the results of an  
19 analysis. Now, granted, this is just one room for one  
20 fire scenario, actually for two fire scenarios. One  
21 room, two fire scenarios. You have the main control  
22 room, whether it is in purge mode with the ventilation  
23 turned off.

24 Here we have used three different models.  
25 Each of these models has highest factor and standard

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1 deviation. We are looking at three different  
2 quantities: the temperature, the heat flux, and the  
3 smoke concentration or optical density near the  
4 operator.

5 And you can work it through from left to  
6 right, and you will notice that, at the end of the  
7 day, you have in the right column the probability of  
8 exceeding, quote, "the damage criteria", the  
9 habitability criteria.

10 What I like about this is that you can  
11 very quickly ascertain that it is not the temperature,  
12 it is not the heat flux; it is the smoke. And, in  
13 particular, it is the smoke when the ventilation is  
14 turned off that is going to be the most likely  
15 phenomena to drive the operators out of the room.

16 CHAIR STETKAR: And in this case, it  
17 doesn't make too much difference which of the two  
18 models you use.

19 MR. McGRATTAN: Right, right, right. And  
20 I think that this will give the reviewer, when they  
21 look at -- I mean, I have reviewed a lot of CFD  
22 papers. I have been asked by the NRC occasionally to  
23 look at some fire model analyses. A lot of times you  
24 get caught up in so many plots and graphs. It looks  
25 like a Ph.D. thesis.

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1                   And what we want to recommend in the  
2 future is answer the question, answer it in a way that  
3 it is clear. In this plot, you can see that, if it is  
4 smoke, when the ventilation is turned off, then a lot  
5 of the questions about the models, uncertainty, and so  
6 forth, can be directed there. So, don't waste your  
7 time with temperatures and heat flux and whatever  
8 else. Let's focus on what is most likely to be the  
9 problem.

10                   I probably carried it out to too many  
11 decimal places.

12                   (Laughter.)

13                   I do this automatically. I mean, it is  
14 probably .9, all right, or very likely, let's just  
15 say.

16                   But it gives the reviewer a very easy way  
17 to look at the analysis, decide what is important,  
18 what should I focus on.

19                   MEMBER BLEY: I have a bunch of questions  
20 on what you didn't bring flags on and a few comments.  
21 And then, if we can, I will work through it with you  
22 and ask some questions.

23                   MR. McGRATTAN: Okay.

24                   MEMBER BLEY: Back in the beginning, we  
25 started with 1855, going after these things, but,

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1 then, we jumped to parameter uncertainty and say that  
2 the right way to deal with that is through sensitivity  
3 cases. And 1855 doesn't quite agree with that. They  
4 give some other ideas.

5 When I get to your chapter on, section on  
6 sensitivity analysis, to deal with this issue, the  
7 kind of general things upfront sound right. To me,  
8 you are always going to have parameter uncertainty,  
9 and you need to deal with it.

10 Oh, just a simple question. I am not --  
11 I probably should be, and Mark probably gave us the  
12 stuff on this -- the benchmark exercise from the  
13 International Collaborative Fire Model Project, is  
14 there a NUREG on that or something?

15 MR. SALLEY: Which one is that? Is that  
16 through the three? Yes, we have --

17 MEMBER BLEY: Yes, exercise No. 3.

18 MR. SALLEY: Uh-hum.

19 MEMBER BLEY: Yes, because it is referred  
20 to here, but I didn't see --

21 MR. SALLEY: There is a separate NUREG for  
22 that.

23 MEMBER BLEY: Okay.

24 MR. SALLEY: And this NUREG/CR, we can  
25 give you another copy, if you need it.

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1                   MEMBER BLEY: Okay. Yes, I don't remember  
2 going through that in the past. So, I would like to  
3 get a look at that.

4                   But the real things I wanted to ask you  
5 about are we get into these sensitivity studies. In  
6 other areas, the way we deal with parameter  
7 uncertainty is to propagate the distributions on the  
8 parameters through the analysis. And for thermal  
9 hydraulics, they have developed kind of a fancy way of  
10 doing that called CSAU, "CSAU," which has a lot of  
11 nice characteristics.

12                   You make a statement, go beyond here. Let  
13 me read it. I am wondering if this is the reason you  
14 don't propose something like that.

15                   "Determining the parameters for the LFS,  
16 however, is more difficult because it is a  
17 mathematically ill-posed problem to take a given  
18 outcome of a fire and go backwards in time."

19                   And I am not sure if that is related to  
20 what I am asking you. Is there an ill-posed aspect to  
21 propagating uncertainties on parameters through the  
22 models?

23                   MR. McGRATTAN: No. If you have a  
24 distribution of a given input parameter, you can get  
25 an equivalent distribution of the outputs based on

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1 that input.

2 MEMBER BLEY: Okay.

3 MR. McGRATTAN: That is a forward process.

4 MEMBER BLEY: Yes, yes, which seemed  
5 reasonable to me.

6 You go through with the example on the  
7 sensitivity study, and all of that makes sense.

8 MR. McGRATTAN: Right.

9 MEMBER BLEY: But when you get to the end,  
10 you point out that only three of these, and primarily  
11 one, have really major impact on the calculation.

12 Two things come to mind there, if we don't  
13 want to propagate the parameter uncertainty through an  
14 analysis using the models. Well, first, the  
15 sensitivity study helps me see what is important, and  
16 then maybe I only propagate the important one through  
17 the analysis. And if I don't want to do that, maybe  
18 I can develop a model of a model using partial  
19 derivatives on these things and somehow address it  
20 that way.

21 But the sensitivity study doesn't in any  
22 way given me the uncertainty, a measure of the  
23 uncertainty. It shows me a couple of examples of how  
24 much something would have to change to do a particular  
25 effect.

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1 MR. McGRATTAN: Uh-hum.

2 MEMBER BLEY: So, it doesn't get to that  
3 integrated look at the uncertainty that is very  
4 helpful to us very often.

5 MEMBER SHACK: Since you were doing these  
6 things by the scaling, I mean, it is an Excel  
7 datasheet that runs in one minute to look at all of  
8 these, sample from all of them, and get bugger factors  
9 to adjust your thing. I mean, there is no need to  
10 look at them one at a time. You could do the whole  
11 thing, and that would sort of address part of Dennis'  
12 question.

13 Then, you really don't believe all these  
14 scaling analyses, but at least it would aim you at the  
15 right calculation maybe to repeat. So, I didn't know  
16 why you were restricting yourself to one at a time  
17 when you didn't have to do that for any particular  
18 reason.

19 MR. McGRATTAN: Again --

20 MEMBER SHACK: I mean, so maybe you can  
21 look at the insight point of view, but I would rather  
22 look at everything and then sort of look at the 95  
23 percentile and see what those cases look like to see  
24 what they might be. At least that would be another  
25 thing to do, in addition to the sensitivity analysis.

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1 MR. McGRATTAN: Well, we are generally  
2 dealing with three kinds of models: the empirical  
3 correlations, zone models, or CFDs. When you are  
4 dealing with CFD models, it becomes very difficult to  
5 propagate these uncertainties as distributions. With  
6 zone models and with empirical correlations, it is  
7 relatively simple just to simply run these  
8 calculations a couple of dozen times.

9 MEMBER SHACK: Sampling from the  
10 distribution.

11 MR. McGRATTAN: And sample from the  
12 distributions.

13 CHAIR STETKAR: Kevin?

14 MR. McGRATTAN: Yes?

15 CHAIR STETKAR: You don't even have to do  
16 that with the empirical correlations because they are  
17 Excel spreadsheets. Take CRYSTALBALL, just sample  
18 from the distributions and do it.

19 MEMBER BLEY: That is essentially what he  
20 said, yes.

21 CHAIR STETKAR: Well, but, I mean, not  
22 running the single calculation several times.

23 MEMBER BLEY: Yes, right.

24 CHAIR STETKAR: I mean, it does that.

25 MEMBER BLEY: And I am not a CFD guy, and

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1 I know it is very complicated. Is the problem there  
2 that it is just too computer-intensive to --

3 MR. McGRATTAN: Time. Time.

4 MEMBER BLEY: -- run the cases?

5 MR. McGRATTAN: Yes. And so, when we --

6 MEMBER BLEY: But they are a model of a  
7 model kind of thing.

8 MR. McGRATTAN: Well, do you know what the  
9 problem is in my experience? People won't do it.  
10 They simply won't do it.

11 If it becomes more difficult to do the  
12 sensitivity analysis than the analysis itself, then  
13 what we find is that people will just dance around it  
14 somehow.

15 Maybe Francisco would like to comment more  
16 on this. But I just find that I have read many papers  
17 about very sophisticated ways of doing sensitivity  
18 analysis, especially with CFD. I rarely, if ever, see  
19 it done in practice.

20 And what we want to do is we want to try  
21 to get these methods out there in a way that people  
22 are actually going to use them.

23 CHAIR STETKAR: You are developing,  
24 though, self-fulfilling guidance. If you tell people  
25 "You don't need to do uncertainty analysis," of course

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1 they won't do it. Because here is, yet, another NUREG  
2 where the U.S. Nuclear Regulatory Commission says I  
3 don't need to do uncertainty analysis, even when I  
4 have simple tools that I can use at least in four out  
5 of the five models.

6 MR. McGRATTAN: Oh, we are not saying  
7 don't do it.

8 CHAIR STETKAR: Yes, you are.

9 MR. McGRATTAN: We are proposing simple  
10 ways to do it, you know.

11 MEMBER BLEY: Well, I don't think that the  
12 sensitivity study really gets you there. It lets you  
13 see the sensitivity, but it doesn't give you a good  
14 picture for -- if you then look at some other piece of  
15 the analysis and wonder what the effect of these  
16 parametric uncertainties would be on that calculation,  
17 you probably don't have it from having done that set  
18 of sensitivity studies. At least, I am not smart  
19 enough to do it.

20 MR. McGRATTAN: Here is what typically  
21 happens: the analyst postulates a heat release rate  
22 for a bag of trash, does some analysis, gets predicted  
23 upper layer temperature. The AHJ comes back and says,  
24 "I don't think you used enough trash. Double your  
25 heat release rate," or, you know, increase it by 50

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1 percent. How is that going to affect your upper layer  
2 temperature?

3 If you are doing CFD, you at least know  
4 that the upper layer temperature goes like the two-  
5 thirds power of the heat release rate change. So, you  
6 could make a very quick estimate of how much it is  
7 going to affect things. If you are running a simpler  
8 model, you can just dial in the increased heat release  
9 rate. That is sensitivity analysis as it is typically  
10 practiced.

11 MEMBER BLEY: I don't disagree with that,  
12 but I think there are some advantages here in getting  
13 at the real uncertainty. We haven't, as a committee,  
14 looked at any of the new fire PRAs, but we have seen  
15 bits of them when they have come through.

16 And just an example from that hits me.  
17 There is a great complaint that the methods are too  
18 conservative. But they didn't do an uncertainty  
19 analysis, so they took the peaks everywhere. Well,  
20 the peaks are high. And if you don't look at the  
21 likelihood of the peak compared to the rest, you get  
22 overestimates, and then you either have to fix stuff  
23 or you have to do more and more hard work to get out  
24 of this spot.

25 MR. JOGLAR: As a practical comment, if we

1 have to run the parameter uncertainty for CFAST in all  
2 these scenarios, in the PRA you would do fire modeling  
3 if it is going to show this is not damaged. Because  
4 you start from the premise that I have damage in all  
5 these cables; even in Appendix R you fail the entire  
6 room. So, you would only do it if you have no -- it  
7 is going to eventually show I have no damage. So, you  
8 start, also, following your conservative inputs, your  
9 98 percentiles, according to the guidance. If that  
10 gets you there, then that is the answer, and it is  
11 also conservatism --

12 MEMBER BLEY: Where it gets people  
13 sometimes is repairing stuff that they probably didn't  
14 have to repair.

15 MR. JOGLAR: Yes.

16 MEMBER BLEY: What John says is true. If  
17 you have got these as spreadsheet models, there are  
18 tools to let you run the simulation that cost you  
19 almost essentially no time to do, once you have set it  
20 up. So, if you set it up in your spreadsheet, every  
21 time you run it, you just essentially -- well, you  
22 have got to put in the distributions instead of the  
23 single point values, but if you put them in as log-  
24 normals, you have got to put in two points instead of  
25 one for every data point.

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1 MR. STROUP: After the first round of  
2 public comments, we specifically took a step back and  
3 said let's not at this point worry about propagating  
4 the parameter uncertainty; let's focus just solely on  
5 the model and figure out what the uncertainty there  
6 is.

7 One of our first meetings after the  
8 reconstitution of the team, Ken Canavan spent the  
9 entire day-long meeting talking about how do I  
10 propagate a fire model that is uncertain, if you will,  
11 through my PRA. And we looked at that and said, wait  
12 a minute, that is a little bit too big a nut to try to  
13 crack at this stage; maybe we ought to just focus on  
14 the models themselves.

15 And one thing Rick and I have been talking  
16 about, and Mark, is they have added to their action  
17 matrix an effort to try to look at how you propagate  
18 the fire model uncertainty into the rest of the PRA.  
19 I mean, it is something that is on the radar screen.  
20 We just aren't exactly sure how to attack it at this  
21 stage.

22 CHAIR STETKAR: Yes, don't confuse  
23 theoretical discussions of expanding scope of  
24 correlating model uncertainties across many different  
25 applications of that model with what our concern is.

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1 Our concern is this is guidance being produced by the  
2 United States Nuclear Regulatory Commission that is  
3 not adequately quantifying parameter uncertainty,  
4 which is the easier of those two concerns. It just  
5 isn't. It is being published in 2012 or 2013 maybe.

6 MEMBER BLEY: That is not to demean what  
7 you have got on modeling.

8 CHAIR STETKAR: I think you have done a  
9 great job on the modeling.

10 MEMBER BLEY: I think it's great.

11 CHAIR STETKAR: You have done better than  
12 anything I have seen anybody do, except you have  
13 dismissed the parameter uncertainty. And the  
14 uncertainty distributions are available.

15 NUREG/CR-6850 is pretty careful about characterizing  
16 essentially all of the basic parameters with  
17 uncertainty distribution.

18 So, this isn't something that users have  
19 to go out and divine out of whole cloth. They are  
20 there, the uncertainties. There's a couple that  
21 aren't, but they talk about all of the basic  
22 parameters they use and the vast majority of the  
23 calculations are there. There are uncertainty  
24 distributions. So, this is not something that is not  
25 documented.

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1           And there are tools. Certainly, for the  
2 algebraic models, there are off-the-shelf tools that  
3 people can use. They are sort of painless. And at  
4 least not to tell someone that you can and should use  
5 those tools for the applications that are easy. And  
6 as we know, the vast majority of calculations that are  
7 done are with those algebraic models in practice  
8 because they run fast and they give you the necessary  
9 results to kind of get you out of the woods.

10           And even how you might use them in the  
11 zone models, although it is more resource-intensive to  
12 do that, but running the model maybe half a dozen  
13 times, sampling from the distribution to get a sense  
14 of the range of uncertainty.

15           CFD models are a different beast. You  
16 know, trying to provide guidance about how to do it in  
17 that context might require some thought.

18           MR. JOGLAR: Yes, my opinion is that, if  
19 the guide comes across as saying not do it or we  
20 recommend not to, that is certainly not our objective.  
21 So, we probably need to revise that language.

22           I agree with you that the knowledge and  
23 the tools to do parameter uncertainty, it is out  
24 there, and probably our guide doesn't have to dwell  
25 into a lot of detail on how you do it or anything like

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1 that. But perhaps we, probably based on these  
2 comments, acknowledge and probably expand our bead on  
3 it.

4 MEMBER BLEY: The process, at least for  
5 the algebraic models, is probably easier than doing a  
6 set of the calculations you are recommending.

7 MEMBER SCHULTZ: It would be very direct  
8 to do it.

9 CHAIR STETKAR: There is another reason  
10 for this, and that is that -- I think there's two  
11 reasons. One is that -- you know, this is my personal  
12 opinion -- I think this agency should across the board  
13 in any type of analysis be emphasizing the need to  
14 explicitly identify and quantify uncertainties. And  
15 it is especially true as we go into some of these  
16 evaluations of fires and flooding and seismic events  
17 and extreme events for which there are broad  
18 uncertainties, that the rigor of identifying those  
19 uncertainties and trying to really quantify them is  
20 something I think needs to be done in the agency. As  
21 I said, that is my personal opinion. I am not  
22 speaking for the Committee.

23 The other reason is that a lot of the  
24 comments that I think we have all been hearing from  
25 the users or the people who are developing these fire

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1 models is, well, the uncertainties are so broad, so  
2 how can we believe the results of any of this? They  
3 always point that the uncertainties are so broad. We  
4 need to collect more data because the uncertainties  
5 are broad. And yet, nobody is quantifying those  
6 uncertainties. It is just a way of saying we can't do  
7 anything because the uncertainties are so broad.

8 Well, quantify them. Let's see how broad  
9 they are. Let's see if the uncertainty in a  
10 particular parameter is consistently driving the  
11 results? And the only way to reduce the uncertainty  
12 in that parameter is to run more tests. That is  
13 worthwhile.

14 But, until you do that and find those  
15 results, you still have this argument that the  
16 uncertainties are so broad and nobody has quantified  
17 them. So, that is another bit of kind of my  
18 motivation for saying we really ought to be addressing  
19 this issue.

20 MEMBER BLEY: I have two little things  
21 more. One is it might have been nice in here, maybe  
22 even upfront where you talk about the three kinds of  
23 uncertainty, to characterize the experimental  
24 uncertainty. It is there if you know what you are  
25 looking at, but it is not quite characterized in words

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1 that might be helpful.

2 In the last section on the summary, a  
3 couple of things kind of jump out. It might be  
4 helpful to do more with them.

5 Model and completeness uncertainty are  
6 closely related. You say that in a couple of places.  
7 Now where that is important and needs some thought is  
8 when you fall outside of the ranges of allegation, you  
9 have to go look for something else to help you out.

10 And giving some advice about how to think  
11 about the completeness issue at that point, when you  
12 are looking for what to do when you are outside of  
13 that range, I think could be helpful stuff. Now  
14 whether that belongs back in Chapter 2 or over here,  
15 I am not sure, but it could be somewhere.

16 There is also a statement -- and this one  
17 just kind of triggered me a little -- "The most  
18 practical way to quantify the combined effect is  
19 compare model predictions with as many experimental  
20 measurements as possible," umpty-umpty-umpty-ump.

21 I am not sure I would say "the most  
22 practical way". The most direct way and the most  
23 comfortable way, but it is also kind of costly, and  
24 you are probably not going to get a whole lot more  
25 experiments, at least for a while. I don't know what

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1 you have got in the pipeline.

2 MR. McGRATTAN: Oh, outside of the nuclear  
3 community, there are many, many experimental datasets  
4 available. We are not lacking for --

5 MEMBER BLEY: That are applicable, that  
6 you could make use of, yes.

7 MR. McGRATTAN: Correct.

8 MEMBER BLEY: Okay. So, that might be  
9 pretty practical then. So, I am not completely --

10 MR. McGRATTAN: They don't have to be  
11 nuclear. We are talking about fire within a  
12 compartment.

13 CHAIR STETKAR: It doesn't know.

14 MR. McGRATTAN: It doesn't know about  
15 reactors or anything else like that, no. There is a  
16 lot of data out there, and I wrote that. And in my  
17 opinion, comparing your model with as much  
18 experimental data as possible, that is the way to go.

19 MEMBER BLEY: A couple more sentences for  
20 the not-as-well-informed would be helpful for people  
21 like me. I think that that is true.

22 I don't completely understand your second  
23 paragraph there. Regardless of the application, the  
24 assessment of model uncertainty is the same, and the  
25 issue of parameter uncertainty is dependent on the

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1 application. And there, the applications you are  
2 talking about are for what is this fire analysis being  
3 done.

4 MR. McGRATTAN: Right.

5 MEMBER BLEY: Which comes clear as you  
6 read on.

7 I am not 100 percent sure I understand the  
8 difference in the two there.

9 MR. McGRATTAN: The difference in the --

10 MEMBER BLEY: Why is parameter uncertainty  
11 dependent on the application? If you had said neither  
12 one is dependent, I wouldn't think much about it,  
13 but --

14 MR. McGRATTAN: I am going to let  
15 Francisco handle this because there's a lot of  
16 discussion about big FM and little FM. Are you  
17 familiar with those terms?

18 MEMBER BLEY: No, I should be, huh?

19 MR. McGRATTAN: Okay, well, I will have  
20 Francisco explain them.

21 MR. JOGLAR: Well, I have to apologize,  
22 but I don't think I know what is the exact question.

23 MR. McGRATTAN: It is, why does parameter  
24 uncertainty, the way we do it, depend on the  
25 application?

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1 MEMBER BLEY: See, I didn't understand it,  
2 either.

3 (Laughter.)

4 MR. JOGLAR: I don't --

5 MR. McGRATTAN: If you are doing the  
6 analysis as part of PRA, I suppose if you are doing  
7 the analysis as part of an 805.

8 MR. JOGLAR: Is that the question?

9 MR. McGRATTAN: Well, I think that is the  
10 answer.

11 MEMBER BLEY: Why is parameter uncertainty  
12 different as you go from application to application?  
13 But it is a matter of what we know about the  
14 parameters.

15 MR. McGRATTAN: Because in some fire  
16 analyses you choose the mean of all the input  
17 parameters; in some analyses you choose these 98th  
18 percentiles.

19 MEMBER BLEY: But that is not parameter  
20 uncertainty. That is, am I trying to be more  
21 conservative or not?

22 MEMBER SHACK: And that is a different way  
23 to deal with uncertainty.

24 MR. McGRATTAN: Right, and that is the way  
25 it is handled now.

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1 MEMBER BLEY: Right. Okay. If that is  
2 what you are saying, that didn't come across to me  
3 here.

4 So, what is a big FM and a little FM,  
5 since you brought it up?

6 (Laughter.)

7 MR. McGRATTAN: Whether the fire modeling  
8 is being used as part of a PRA --

9 MEMBER BLEY: Oh, okay.

10 MR. McGRATTAN: -- or whether it is being  
11 used in some other way. And there are different  
12 rules, if you will --

13 MEMBER BLEY: Okay.

14 MR. McGRATTAN: -- for how to treat --

15 MEMBER BLEY: The idea that these are  
16 rules about the conservative level of the analysis  
17 didn't jump off the page. What jumped off is saying  
18 the parameter uncertainty depends on it. Well, it  
19 doesn't. The parameter uncertainty is the parameter  
20 uncertainty. It is whether you treat it or not or  
21 whether you try to bound it or whether you ignore it  
22 or whether you treat it by doing a mean.

23 MR. McGRATTAN: That is what was meant by  
24 it.

25 MEMBER BLEY: And that, it certainly just

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1 didn't come across.

2 MR. McGRATTAN: Okay.

3 MEMBER BLEY: So, it is not a complaint  
4 about the methodology or anything else.

5 MR. McGRATTAN: Okay.

6 MEMBER BLEY: It is just a matter of text.  
7 I didn't get that.

8 CHAIR STETKAR: And by the way, Dennis  
9 mentioned it; I have precisely the same comment.

10 MEMBER BLEY: We didn't trade.

11 CHAIR STETKAR: I swear we didn't --

12 MR. JOGLAR: This is the second paragraph  
13 on which page?

14 MEMBER BLEY: The last paragraph of --

15 CHAIR STETKAR: Section 4.5. There's only  
16 two paragraphs. This is the second one.

17 MEMBER BLEY: It is the last one in the  
18 whole section.

19 I think that's it.

20 CHAIR STETKAR: Anything more on Section  
21 4?

22 MEMBER SCHULTZ: Just a general comment.  
23 In reading the text, I didn't get this impression.  
24 But in hearing some of the discussion today, I did.  
25 And that impression I hope doesn't carry forward.

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1           The impression was that in Chapter 3 and  
2 then part of Chapter 4 the focus of the document is  
3 for the user, the user in performing the modeling  
4 evaluation.

5           Then, in Chapter 4, the uncertainty  
6 evaluation or the evaluation of the models was  
7 something that the reviewer, the regulator, would pay  
8 more attention to in reviewing what the user had done.  
9 In the text, that is not how it is presented. It is  
10 presented that it is the users' responsibility to  
11 determine and justify the models that are chosen, and  
12 that involves both the work and the model selection as  
13 well as the sensitivity evaluation, the uncertainty  
14 analysis, and that as part of the justification.

15           MR. JOGLAR: Yes.

16           MEMBER SCHULTZ: I just wanted to make  
17 sure that, walking forward, we are not expecting the  
18 reviewer is responsible or has the job of determining  
19 whether the model selection and justification, the  
20 model selection was appropriate. It is the user that  
21 needs to pull all that forward.

22           MR. McGRATTAN: Do you want to comment on  
23 that?

24           MR. JOGLAR: Yes. I think our guide,  
25 since Chapter 2, the intent has been I think in

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1 Chapter 2, or at least the process, one of the steps  
2 I think at the end is do these uncertainty and  
3 sensitivity analyses. And always we have intended  
4 that all these methods are for the analysts to cover  
5 all the ground, and the regulator will just expect to  
6 see that treatment in the analysis. So, I don't think  
7 we were intending that these uncertainties are  
8 something that will be done by --

9 MEMBER SCHULTZ: That's fine. And I saw  
10 that in the documentation. In some of the phrasing,  
11 as we went through the discussion today, I heard  
12 something about the reviewer would use this portion of  
13 the technology to evaluate whether the user had done  
14 it. I wanted to be sure that that didn't carry  
15 forward.

16 MR. JOGLAR: Well, I mean, it is certainly  
17 a tool for the reviewer to understand the  
18 uncertainties. But our intent is that, as part of  
19 your fire-modeling analysis, you would do the  
20 sensitivity and the uncertainty.

21 MEMBER SCHULTZ: That's fine. That's why  
22 I asked.

23 MR. JOGLAR: And also, I think we were  
24 always also saying that, as part of a specific  
25 application, there is always going to be interaction

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1 between the plant and the regulator in terms of what,  
2 quote/unquote, "acceptable" for a specific  
3 application. But that is, in my view, unavoidable.  
4 But our process is intended to be done by the analyst.

5 MEMBER SCHULTZ: And that is why I agree  
6 with Dennis and John that bringing in the analysis  
7 associated with the parameter uncertainty would add  
8 emphasis to that, put it on the table for the analyst,  
9 the user of the tools, to assure that that is also  
10 incorporated in the analysis. It is important to do.  
11 It gives the analyst the full responsibility of  
12 evaluating all of that.

13 CHAIR STETKAR: Any other  
14 comments/questions on Chapter 4?

15 (No response.)

16 Good.

17 You guys want to show us some real models,  
18 real analyses, right?

19 MR. JOGLAR: So, as you may have seen in  
20 our guide, the examples are a good portion of it. It  
21 was, in addition to the treatment of uncertainty, the  
22 source of a number of comments. I will point out that  
23 consistency in the treatment of examples and input  
24 values within an example, between examples, and  
25 between the main body of the report and the

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1 appendices, was a source of a number of comments.  
2 Even minor differences between "You said 200 and it's  
3 205 here" were a good portion of comments. And we  
4 spent a lot of time making sure that our treatment  
5 between chapters, between chapters and the appendices,  
6 was consistent.

7 So, another point that took us some time  
8 is we solved some of these examples with different  
9 tools. And making sure our guidance is consistent and  
10 building the proper way of using the models, and the  
11 results are interpreted correctly, even that the  
12 different tools will not give you identical results,  
13 was also an area where we spent quite a bit of time  
14 making sure that the guidance was clear.

15 Okay. So, these examples are typical  
16 scenarios in the power plants. We have seen them. We  
17 walked them down. On my application side of my work,  
18 I saw very similar scenarios to these many times.

19 The other objective of having these  
20 examples is that we wanted to create a consistent  
21 template for analysis and review. So, if somebody  
22 wants to now do a fire-modeling analysis, they should  
23 be able to open up one of our appendices and see a  
24 full structure with sections and the kind of  
25 information that would be recommended, and maybe we

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1 can say expected.

2 So, we hope that this serves as some  
3 consistency, it brings some consistency into the  
4 practice of developing these fire models and  
5 reviewing, because people know what to expect, what  
6 should go in.

7 And, of course, we paid a lot of attention  
8 to the requirements of NFPA 805 and the requirements  
9 of the fire PRA standards in terms of fire modeling to  
10 make sure our guidance covered that. And we have  
11 pointed out in this meeting areas where maybe some  
12 additional guidance is necessary. We recognize that,  
13 and it has come up in the meeting. For example, we  
14 were talking about the maximum expected and limited  
15 scenario. But we did try to develop these appendices  
16 following the current practices and standards.

17 You will see that our examples are closely  
18 related to that sketch that we presented in Chapter 3.  
19 That was qualitative. This is the real thing. This  
20 is where we go into detail and solve these with one or  
21 more models. We pose a very specific question to  
22 answer that is very practical, and we try to offer a  
23 solution at the end.

24 As we have discussed, these are real  
25 examples. We didn't select them to match the

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1 capabilities of the model or to match the V&V ranges.  
2 We picked an example and tried to do the best we can  
3 with the tools available to solve them, and our  
4 discussion should reflect that.

5 The first one is the control room for  
6 habitability purposes. You see here how the control  
7 room looks like. It has a complex geometry. It has  
8 intervening combustibles. It has an initial source.  
9 It has mechanical ventilation. All of those are real.  
10 The size is about the size of a single-unit control  
11 room. So, it is all within the range of practical  
12 applications.

13 The second one, it is a typical cable  
14 spreading room or switchgear room, and it addresses a  
15 fire affecting cable trays. That is by far the most  
16 common scenario analyzed, some cables exposed to a  
17 fire nearby.

18 It has the complexity of a number of cable  
19 trays, which just by adding a number of cable trays  
20 makes this a complex problem in terms of fire  
21 modeling. So, that is why we see that geometry there.

22 Modeling large fires in small rooms,  
23 although in a fire PRA we may say fail it. Okay? We  
24 have a big fire; let's figure out the frequency; fail  
25 it. There are applications where a model may be

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1 needed, and we presented an example here where we are  
2 trying to evaluate if a wrap is good. It puts the  
3 burden on the analyst to figure out the parameters  
4 characterizing that wrap. But if it is necessary, we  
5 provide an example of it.

6 Again, you can see that we are using  
7 geometries that are not a standard box, and this is  
8 intentional, not only because it is real, but it  
9 forces us to give guidance on what to do, and the  
10 model requires you to set it up as a box, right.

11 The next one, it is very similar to the  
12 sketch where we have a large room, and those are also  
13 fairly typical, with complex geometry and targets that  
14 are far away. This highlights the ability to use CFD  
15 to calculate, let's say, smoke-detection time if the  
16 smoke detector is placed far away from the fire, or  
17 temperature using a target that is far away. That is  
18 the reason, primary reason, we have it.

19 This is very similar to, Example E is very  
20 similar to a cable spreading room in that we walk down  
21 where there is a relatively-smaller electrical room  
22 inside that bigger cable spreading room. And this is  
23 a type of room that you go in and you can't see the  
24 ceiling, even the large amount of trays there.

25 And so, we went to great extents to model

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1 it as realistically as possible. I think in this  
2 example we even used the FLASH-CAT model to come up  
3 with heat release rates for multiple cable trays. So,  
4 we are trying to use state-of-the-art in this kind of  
5 application.

6 Finally, the large turbine building fire,  
7 you can see the oil tanks there. These primarily are  
8 the structural integrity, although we are careful in  
9 saying we are just calculating conditions and we are  
10 not doing a structural analysis. But in the case that  
11 you need to evaluate it, I mean, we give you one of  
12 the steps to complete that, which is the fire  
13 environment, the fire-generated environment around it.

14 In the fire PRA standard, there are  
15 requirements for evaluating multi-compartment fires,  
16 and fire modeling in multi-compartment fires is done  
17 somewhat routinely. So, we have guidance on how to  
18 build and analyze fires where the impact, the fire-  
19 generated condition may go up among different rooms  
20 for both detection, target damage, and maybe in some  
21 HRA application determining what are the fire  
22 conditions in an adjacent room. That example is  
23 included also.

24 And finally, we went through a really  
25 challenging one, which is a fire in the containment

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1 annulus and how to model those.

2           So, we think these are not straightforward  
3 boxes with a fire. They cover a wide range of  
4 applications. Of course, there are more difficult  
5 ones. But, for guidance, we think that these  
6 examples, for whatever application you have, you  
7 should find a very close template in our appendices to  
8 start off and give you good guidance for both the  
9 people preparing it and the reviewers on how to  
10 analyze it with multiple models.

11           MEMBER BLEY: I hope people use it that  
12 way and start off with it, rather than just trying to  
13 duplicate it, you know.

14           MR. McGRATTAN: Okay. What I think I will  
15 do here is just walk you through one of these  
16 appendices, just to show the process that we go  
17 through. And as you read through them, this process  
18 is fairly similar case-to-case. So, Dave already  
19 introduced the basic steps, and I will just go through  
20 them one-by-one.

21           So, the first step in any fire-modeling  
22 analyses is just simply to state in simple terms the  
23 objective. In this case, this is the control room  
24 scenario, and the purpose of the calculations is to  
25 determine the length of time that the main control

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1 room remains habitable. In 6850, there is a  
2 definition of what that means. Basically, it means  
3 that the temperature, heat flux, and smoke  
4 concentration have to be maintained below certain  
5 critical values.

6 And we describe the scenario, the most  
7 important parts. You know, a nice drawing of the  
8 space. We include in here enough detail so that you  
9 can model this either with a simple model or with a  
10 CFD model, to try to include all the geometry.

11 Then, we follow that up with one of the  
12 most important input parameters, and that is the heat  
13 release rate. The heat release rates in all these  
14 scenarios is typically taken from 6850. In this case,  
15 we are told that we have a cabinet of a certain type.  
16 Go to 6850, and the recommended 98th percentile heat  
17 release rate is shown in this figure.

18 There was a supplement to 6850 that got  
19 into some of the details about how you actually apply  
20 that source of energy in the model. It seems from  
21 this diagram -- there's a lot of nitty-gritty here,  
22 but this is a problem that has come up again and  
23 again. That is, different models have different ways  
24 of characterizing the volumetric expanse of the heat  
25 release rate. If you put on the cabinet, the side of

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1 the cabinet -- you know, we did some calculations  
2 where we put it with the CFD model inside the cabinet,  
3 just to see what the effect would be.

4 We also list some of the other important  
5 parameters. And here's something that we got that we  
6 didn't do well at the beginning. That is, we used a  
7 lot of parameters, but we didn't justify or document  
8 them very well. So, the second time around, we made  
9 sure that we wanted to describe what numbers we were  
10 using and where we got them.

11 A lot of times in fire protection  
12 engineering, for example, the rate of diffraction of  
13 the heat release rate is about one-third. So, one-  
14 third of the energy from a fire is radiated; two-  
15 thirds is convected upwards. It is just one of those  
16 rules of thumb that we always use.

17 And we are actually asked to justify that  
18 number, like we started out in the beginning, where  
19 does that number come from?

20 (Laughter.)

21 MR. JOGLAR: And the point Kevin is making  
22 is this is the type of review we got. Consultants are  
23 very concerned on how they write their reports to make  
24 sure there is enough justification so that we can have  
25 a positive exchange with the regulator. And that is

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1 where I was making the point that consistency, given  
2 this kind of comment, is probably going to be  
3 increased.

4 MR. McGRATTAN: Yes.

5 Next in the process is to select the fire  
6 model.

7 MEMBER BLEY: Since you just brought that  
8 up, did you guys get NRR to look at your examples and  
9 see what they would say about them?

10 MR. JOGLAR: Well, they reviewed our  
11 report. I mean, Dave, you can probably talk about  
12 that better than I can.

13 MR. STROUP: Yes. Well, we had one member  
14 of the NRR staff review it as part of the peer review,  
15 the original document, and provide comments. And  
16 then, they gave it to one of their contractors who is  
17 actually doing the 805 reviews now, the second public  
18 comment draft.

19 MEMBER BLEY: Okay. So, they took a look  
20 as if they were reviewing a submitted analysis?

21 MR. STROUP: Yes. Well, that is -- I  
22 won't call it a big difficulty, but that is always an  
23 issue, is we try to maintain some level of distance  
24 between the research and the regulatory arm. But, at  
25 some point, you have got to make that crosswalk, so it

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1 comes out working together.

2 MEMBER BLEY: It would be nicer to look  
3 before some poor guy submits one. "What the heck is  
4 this?"

5 (Laughter.)

6 CHAIR STETKAR: Well, no, that is valid  
7 because of some of the things I mentioned earlier.  
8 The bridge between the two Divisions is the user who  
9 will take this as guidance, process it, and then go to  
10 NRR and say, "Well, we used this wonderful guidance."

11 MR. McGRATTAN: Right. We worried about  
12 them taking it as gospel.

13 CHAIR STETKAR: And they will, yes.

14 MR. McGRATTAN: Because, as you go through  
15 any fire-modeling analysis, you make a lot of  
16 judgments, based on your own experience and so forth.  
17 We worried, because we are modelers, is this going to  
18 become the letter of the law?

19 We said here we are assuming that we are  
20 going to assume the properties of concrete instead of  
21 chipboard, when we have the two types of materials in  
22 the room. Does that now become the standard, the  
23 gospel?

24 And what we wanted to emphasize more was  
25 make an assumption and justify why you are making it.

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1 It is actually more important, the justification as to  
2 why you are making that assumption.

3 CHAIR STETKAR: Well, I think that is what  
4 Alex was saying earlier, that the burden is on the  
5 user to convince the reviewer that what they have done  
6 is adequate for the application. It might not be the  
7 perfect analysis --

8 MR. McGRATTAN: Right.

9 CHAIR STETKAR: -- but it is adequate for  
10 the application.

11 And as long as the guidance in this  
12 document kind of sticks to that same mantra, it should  
13 all work.

14 MR. McGRATTAN: Yes. So, this third  
15 section, the selection of the fire models, this is  
16 new. In my experience with fire modeling, this is  
17 new, where now, before you select that model, you need  
18 to look at the scenario that you are going to analyze,  
19 and you calculate these six non-dimensional  
20 parameters. And you ask yourself, is this model  
21 capable of computing in this range of parameters? Has  
22 this model been validated for this application?

23 As I said before, in all eight cases the  
24 answer was no for some of the parameters. In this  
25 case, there were three of the six parameters that fell

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1 outside of the validation space, and it is now up to  
2 the user to justify why they are going to use a  
3 particular model for this analysis.

4 And just to give you an example of how  
5 that would be done, in one of these scenarios we have  
6 no ventilation in the room. So, technically speaking,  
7 you can't calculate the equivalence ratio because  
8 there is no airflow at all into the room. You get a  
9 nonsensical result.

10 So, how do you know that it is okay to use  
11 a particular model for this? Well, you can say, how  
12 much oxygen is there in the room, and is there enough  
13 oxygen in the room to sustain the fire? And you can  
14 do a very simple calculation to say, with this much  
15 oxygen, this fire is going to consume this much, and  
16 we are good to go. Okay?

17 It doesn't take much. I mean, what I am  
18 showing here on the screen is the justification. It  
19 doesn't have to be lengthy, but it has to be something  
20 to justify why you are outside the validation space.

21 Okay. Next --

22 MEMBER BLEY: You just brought up  
23 something that I hadn't thought about before.

24 MR. McGRATTAN: Yes. Okay.

25 MEMBER BLEY: I should have.

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1           We have had a few interesting fires, some  
2 really widespread, but some in very localized areas,  
3 such that you could probably model those pretty well.  
4 I wonder, I know we have validated against experiment,  
5 but have we tried to validate against any actual real  
6 fires out there to see if the models actually perform  
7 in the way we think they do from the experimental  
8 validation?

9           MR. McGRATTAN: We have done that not  
10 necessarily for nuclear applications, but the World  
11 Trade Center is a good example where NIST did the  
12 investigation of the collapse of the World Trade  
13 Center.

14           Part of the validation of the model were  
15 the thousands and thousands of photographs that were  
16 taken. So, as we made predictions of where the fire  
17 was and how it progressed over the different floors  
18 and around the building, we compared our calculations  
19 with these photographs.

20           I am not aware -- and, Francisco or Mark,  
21 you might be more aware of -- have there been  
22 investigations, fire-modeling investigations, in the  
23 nuclear community?

24           MR. JOGLAR: Well, Rick, you can elaborate  
25 it. But my view of this is this recent effort of

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1 collecting all these data is going to help quite a bit  
2 on that, because it is going to give us enough  
3 information to compare.

4 So, I don't think the data we have now has  
5 enough without going into the plants. Like, for  
6 example, there may be an interesting fire in the  
7 1980s, and we have a paragraph describing the event.  
8 That may not be enough to do a full comparison with  
9 the capabilities of the model without going and maybe  
10 interviewing some guy that --

11 MEMBER BLEY: Well, a couple of the real  
12 interesting ones were investigated in substantial  
13 detail.

14 MR. JOGLAR: Right. So, in the real  
15 interesting ones that I am aware of, of course, there  
16 have been these high-energy arcing faults, and those  
17 have been investigated. But, for those, our model  
18 capabilities are not there and we treat them  
19 elsewhere.

20 So, some of the interesting ones, we see  
21 the effects in our analysis, not necessarily in fire  
22 models. So, perhaps, as I said, we have all these  
23 good data now; there may be a few that maybe we can do  
24 that type of exercise.

25 MR. SALLEY: Yes, it is a very interesting

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1 comment you make. And I go back to when Naim and I  
2 originally wrote 1805. We worked with ATF. And we  
3 kind of looked at their world versus our world.

4 In the ATF world, they were always trying  
5 to reconstruct an event that happened to prove, yes,  
6 this is physical and they're telling the truth. So,  
7 that was their world. Where our world was the exact  
8 opposite, where you had an inspector out there, and he  
9 says, "Here's what can possibly happen." So, we  
10 always look at the problem from two different ways.  
11 We were looking into the future to see what we  
12 predict, where they were trying to look into the past  
13 to justify how it happened.

14 Francisco brings up one other really good  
15 point, and that is the high-energy arcing fault. You  
16 know, there is a case where we know and we see things.  
17 We see San Onofre. We see Robinson. But when I say,  
18 "Okay, Kevin, here's some off-the-scale heat release  
19 rate for one-eighth of a second. Run me a model," it  
20 doesn't work. Okay?

21 (Laughter.)

22 We just can't do it. So, we have to look  
23 at other things, and we have got other programs. We  
24 are going to go for the zone of influence. And then,  
25 we have got a whole new experimental program we are

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1 going to go international with.

2 MEMBER BLEY: I was just remembering there  
3 were a couple of fires. There was one in the  
4 Northeast where the room burned for about a half-an-  
5 hour. You know, something like that might be  
6 interesting to see how these do against that.

7 MR. STROUP: Yes.

8 MEMBER BLEY: Not the investigation, to  
9 know how it started and how long it took to --

10 MR. McGRATTAN: But what would be the  
11 metric of success? In other words, what would you  
12 compare your model prediction against?

13 MR. JOGLAR: A better way of making my  
14 point, that we will need enough information to say  
15 yes.

16 MEMBER BLEY: Something was not on the  
17 PRA.

18 MR. McGRATTAN: If you had, for example,  
19 you know, a melted light fixture or something like  
20 that, that might indicate a certain temperature at a  
21 certain place, and you could qualitatively compare.  
22 I can see how that could possibly be done.

23 MEMBER BLEY: Essentially, when you did  
24 the World Trade Center, you looked at -- I don't know;  
25 you might have had to modify your models as you went

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1 to match up with what had actually happened there.

2 MR. WACHOWIAK: That is one of the things  
3 that is also on the EPRI fire PRA action matrix  
4 starting this year.

5 MEMBER BLEY: Is it really?

6 MR. WACHOWIAK: It is to look at the fires  
7 that we have in the database and try to get a better  
8 understanding of what actually happened during the  
9 fire. What was the progression? What was the real  
10 heat release rate? And you do that by looking at  
11 things like what was damaged and compare it.

12 But I am not sure we are trying to  
13 evaluate the models in that case. I think in that  
14 case we are more using the validated models to  
15 understand better the parameters that would go into  
16 the models. That is the angle we would be taking it  
17 there.

18 So, maybe by taking a fire that happened,  
19 if we know what the damage was from that fire, we  
20 would use the model, then, to evaluate what type of  
21 heat release rate or what mass of fuel burn, and  
22 things like that, would have to go into this in order  
23 to cause the damage that we observed. So, it is more  
24 validating the input parameters rather than validating  
25 the models at that point.

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1 MR. JOGLAR: It is not a V&V --

2 MR. WACHOWIAK: It is not a V&V model. It  
3 is a better understanding of what the actual fire was.

4 MR. JOGLAR: -- in 1824, where we have  
5 data to actually do --

6 MEMBER ABDEL-KHALIK: An empirical fit.

7 MR. JOGLAR: Yes.

8 MR. WACHOWIAK: Yes, and it is to gain  
9 insights for the fires. But that is one area that we  
10 want to look at. Maybe that would help us understand  
11 better the propagation of parameter uncertainty and  
12 model uncertainty that you would use in a PRA.

13 That is at least my long-term goal, is to  
14 help understand how the total treatment of uncertainty  
15 would go into the PRA model versus the issues with  
16 picking all the peaks and everything associated with  
17 bounding values. Because if you are not going to use  
18 the bounding values, you have to have a better  
19 treatment of the uncertainty.

20 MR. McGRATTAN: Okay. Next, once the  
21 models are selected, now you need to describe how they  
22 are run. And typically, we start with the empirical  
23 correlations and move up, depending on if there is a  
24 need for it.

25 So, in this case, it is a situation where

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1 we have a closed room with ventilation. There is  
2 actually a correlation or the FPA -- the Foote, Pagni,  
3 Alvarez Correlation -- or closed ventilated  
4 compartment.

5 As you can see here from this sketch, you  
6 know, it requires fairly little input information:  
7 ventilation rate, fire size, and the volume of the  
8 room. And it predicts a rough average temperature  
9 throughout the whole space.

10 Now, if the only objective of this  
11 analysis were to determine the temperature in the  
12 room, and the temperature from this analysis were  
13 sufficiently low -- and I will leave it to you to  
14 describe what that would be; let's just say it was  
15 -- then maybe the analysis stops there. Okay? That  
16 is sort of the screening approach.

17 But in this case we are not only  
18 interested in temperature. We are interested in heat  
19 flux, and we are interested in smoke concentration.  
20 So, the empirical correlations don't provide us with  
21 all the answers.

22 So, we move on to the zone models. And  
23 these are just some snapshots from the zone model  
24 called CFAST showing typical input parameters, how  
25 they are put in. The heat release rate is dialed in.

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1 The various parameters that I showed on the screen are  
2 put in. And you get a temporal evolution of the upper  
3 layer temperature and lower layer temperature in the  
4 room.

5 Now, again, if this doesn't address all of  
6 the criteria, or if the analyst decides that this  
7 doesn't adequately describe the physics, then the next  
8 option is to move on to Example CFD. This is an  
9 output from the Fire Dynamics Simulator. It shows the  
10 smoke from the cabinet starting to spread throughout  
11 the room. So, you can see now that you don't have  
12 just a uniform concentration of smoke or temperature,  
13 but there is a three-dimensional distribution.

14 As I showed before, once you have run all  
15 these different models, you can assess their  
16 uncertainties and calculate probabilities of exceeding  
17 the critical values of temperature, heat flux, and  
18 smoke concentration. And this is the same plot I  
19 showed before. So, in this case, it was the optical  
20 density in the case with no ventilation that is a  
21 cause for concern. And that is where we might spend  
22 extra time in the discussion describing how the  
23 different models are handling this.

24 And here is where we use sensitivity  
25 analysis. And I will describe how we do it. In this

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1 case, there were two parameters that were very  
2 important. One was smoke yield from the fire. That  
3 is, the amount of smoke per unit mass of fuel consumed  
4 that this fire would generate. And the other was the  
5 rate of diffraction, how much of the energy from the  
6 fire is radiated.

7 I mentioned before that we had originally  
8 just made some ballpark assumptions for these two  
9 values based on our own experience. One I think was  
10 5 percent for the smoke yield, and we used one-third  
11 for the rate of diffraction.

12 But the reviewers called us on that, and  
13 they said, "Wait a second. Why are you using those  
14 numbers." We said, "Well, these are typical numbers."  
15 They said, "No, no, no. We want you to justify them."

16 So, we went to the SFP Handbook, the  
17 Society of Fire Protection Engineering Handbook, and  
18 we found for this kind of plastic material on the  
19 cables that were in the cabinet we have got a smoke  
20 yield of, I believe it was, .17 -- it is a relatively-  
21 high smoke yield -- and rate of diffraction of .53,  
22 which is considerably higher than about .35, which is  
23 what we typically use.

24 And so, what the advice we give to the  
25 user is, since this is the phenomena that is most

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1 likely to force the operators from the room, look more  
2 closely at these parameters. And so, we did  
3 sensitivity analysis to show how much would the  
4 evacuation -- or what's the term? How would it change  
5 the time to abandonment, depending on whether you used  
6 the one-third that you would typically use as opposed  
7 to the .53?

8 So, this is typically how sensitivity  
9 analysis is used in practice. I appreciate what you  
10 are saying about the propagation of the distributions,  
11 but this is typically how sensitivity analysis is used  
12 throughout our examples, to look at those parameters  
13 that play a critical role in, in this case, causing  
14 that room to become uninhabitable.

15 MR. JOGLAR: And these results, you know,  
16 we made the point that these are real applications.  
17 This is what I have seen in many control room  
18 analyses, where we were saying, if you don't have this  
19 purge system, you are going to be forced to abandon it  
20 pretty quickly because that is how smoke develops.

21 MR. McGRATTAN: Right.

22 MR. JOGLAR: I mean, it's quick.

23 MR. McGRATTAN: Right.

24 MR. JOGLAR: It is very quick. And we  
25 have seen it, also, in experiments.

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1 MR. McGRATTAN: Right. And how fast, you  
2 know, when there is a criteria of three inverse meters  
3 for abandonment, these are the two opinions from the  
4 zone model and CFD. We looked at, you know, how much  
5 would these times shift based on those critical  
6 parameters that we input?

7 MEMBER BLEY: Let me clarify something I  
8 said earlier.

9 MR. McGRATTAN: Yes.

10 MEMBER BLEY: In this case, I think I  
11 wouldn't even call these sensitivity studies. I would  
12 call these examinations under two different  
13 conditions, each one of which could be modeled in a  
14 PRA.

15 MR. JOGLAR: I agree.

16 MEMBER BLEY: Yes. So that I certainly  
17 wouldn't advocate taking some kind of a distribution  
18 on the likelihood of the fans being working and show  
19 uncertainty distribution of that type.

20 MR. JOGLAR: And the way I have seen it is  
21 both cases are wrong, and you just pick the worst  
22 numbers and see if you can live with them.

23 MEMBER BLEY: That's the first cut.

24 MR. JOGLAR: Well, both analyses are  
25 there.

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1 MEMBER BLEY: Yes. And if you somehow  
2 have procedures or something you were trying to model,  
3 you could actually couple those cases --

4 MR. JOGLAR: Or invoke into the model the  
5 need for what is the likelihood that this purge system  
6 is not going to operate --

7 MEMBER BLEY: Exactly.

8 MR. JOGLAR: -- because of operator  
9 activation.

10 MEMBER BLEY: That is what I was trying to  
11 say.

12 CHAIR STETKAR: But, I mean, in principle,  
13 that is a branch point in the PRA model.

14 MEMBER BLEY: Right.

15 CHAIR STETKAR: You know, it doesn't  
16 affect -- you still have to run both calculations.  
17 This just gives you a different time for each of those  
18 sequences.

19 MEMBER BLEY: Right, but that is a nice  
20 point because where you would look for distributions  
21 on parameters is really dependent on how you were  
22 going to model these in the PRA.

23 CHAIR STETKAR: Right.

24 MEMBER BLEY: So, the treatment aspect  
25 would be different. But if you are looking at PRA,

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1 there are some things that are parameters that have a  
2 range of uncertainty under essentially all different  
3 conditions that you would want to try.

4 MR. McGRATTAN: Right, right.

5 MR. JOGLAR: But Kevin made the point we  
6 are talking less than 10 minutes -- or less. When we  
7 make this point to non-fire people, like in training,  
8 they say, "Do you really model for less than 10  
9 minutes?" It is consistent with experiments. Where  
10 there is more fire in this room, you see smoke all  
11 over the place very quick. And that is why we see  
12 really this, what we have --

13 MEMBER BLEY: That is probably a surprise  
14 to a lot of people, 10 minutes.

15 MR. JOGLAR: Yes.

16 MEMBER BLEY: Yes.

17 MR. JOGLAR: But you show them  
18 experimental results and quickly they say, "Well...."

19 MR. McGRATTAN: Okay. And finally, just  
20 the conclusion and references. The point here is  
21 that, again, a lot of fire model analyses get caught  
22 up in a lot of details, lots of plots and graphs.  
23 Sometimes they don't answer the question that was  
24 posed.

25 (Laughter.)

1           And even some of our initial writeups of  
2 these scenarios, I mean, someone again called us on it  
3 and said, "But the point was, and then you are talking  
4 about all these other details." We were talking about  
5 these details. We thought they were interesting.

6           (Laughter.)

7           "Answer the question. What is the answer?  
8 When do we have to abandon this room?"

9           CHAIR STETKAR: Take that approach and  
10 convolute it with electrical engineers, who just love  
11 to run little analyses of 37-conductor cables, and all  
12 the different combinations --

13          MR. McGRATTAN: Right, right.

14          CHAIR STETKAR: -- there's your problem.

15          (Laughter.)

16          MR. McGRATTAN: Yes, and if you have spent  
17 time on these things, you want to present it. But  
18 that often, as I said -- when Francisco is doing his  
19 hundreds, or even thousands, of analyses, you know, it  
20 is hard to work through thousands of pages of  
21 analysis.

22                 So, we want to emphasize with these  
23 examples as a template that you don't have to write a  
24 10-page conclusion. If you've got good justification  
25 for your answer, you know, maybe this is all you need.

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1 MR. JOGLAR: Or you don't have to have 250  
2 columns of output out of the model. We, hopefully,  
3 give enough guidance to say, "These are the ones you  
4 pick to solve this issue."

5 MR. McGRATTAN: Yes, yes.

6 MEMBER SHACK: Your last sentence versus  
7 the table, I thought CFAST, in fact, predicted that  
8 you would have to abandon.

9 MR. McGRATTAN: This is addressing the  
10 case where the purge system is on. So, there's two  
11 scenarios here that we are looking at. One is in  
12 which the purge system is on. That is pulling smoke  
13 out, pulling smoke out of the room. And there's  
14 another scenario in which the purge system is turned  
15 off. Essentially, there is no ventilation. It is the  
16 case where there is no ventilation where the room  
17 simply fills up with smoke and it becomes  
18 uninhabitable.

19 So, we are actually making the case, if  
20 you did have the purge system on, it would remain, I  
21 believe, if I recall, that it would remain habitable.

22 MEMBER SHACK: A .36 probability.

23 MR. McGRATTAN: Yes. Yes. And then, the  
24 .36 probability is something that the reviewer can  
25 take in the sense that, however he or she or she

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1 wants --

2 MR. JOGLAR: Yes, and it is done in the  
3 PRA. This is a chance to get out and you model that  
4 as a branch in your analysis. I mean, we discuss  
5 other reasons to leaving.

6 CHAIR STETKAR: Any other questions on the  
7 example?

8 MEMBER SHACK: How well did your scaling  
9 for the sensitivity match in this case? Was it  
10 linear, as it is predicted in the table?

11 MR. McGRATTAN: Well, in this case it is  
12 linear because we are just transporting the smoke and  
13 it is not depositing on the wall. So, it is perfectly  
14 linear. In reality, it is not perfectly linear  
15 because it does deposit on the walls.

16 MR. SALLEY: I can just do it from the  
17 side. Give me the slide, Kevin.

18 CHAIR STETKAR: Just make sure you are  
19 near a microphone. Speak into the microphone.

20 MR. SALLEY: Yes. We timed it pretty good  
21 there. I think we had it until 5:30. So, we've got  
22 a little more time if you want to catch anything else,  
23 and I would more than welcome that. Plus, we need to  
24 stay later.

25 The bottom line is you can see the

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1 timeline of this project, the history of it. For  
2 where we are at, we believe that this is pretty much  
3 ready for primetime.

4 Yes, we did get some good comments out of  
5 you. I think we do need to make some adjustments. Is  
6 that a fair statement to you guys?

7 MR. JOGLAR: Repeat it again, please?

8 MR. SALLEY: We did get some good comments  
9 here today, and I think we do need to make some  
10 adjustments to the document. But I feel pretty  
11 comfortable overall that we can make those  
12 adjustments. Rick and I were talking. Is that the  
13 thought of the team?

14 MR. McGRATTAN: The issue of sensitivity  
15 analysis, I don't think that is trivial.

16 MR. SALLEY: I didn't say "trivial". But  
17 I think it is a solvable problem. It is solvable --

18 MR. McGRATTAN: Everything is a solvable  
19 problem, but I think that that sensitivity analysis  
20 needs to be looked at carefully, in light of the fact  
21 that in a lot of these scenarios we have chosen sort  
22 of the 98th percentile fire. I am not sure what it  
23 means in that context to propagate, for example, the  
24 distribution of heat release rates. That is a  
25 different analysis.

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1 MR. JOGLAR: If I understood the point, it  
2 is that we are missing guidance on parameter  
3 uncertainty. I think we were in agreement that this  
4 is a solvable issue, that the tools are there. I  
5 think it is well-covered in the literature. So, I  
6 don't know how -- you know, to recognize it and to  
7 give guidance, I believe that we can get to a place  
8 that that can be done.

9 MR. McGRATTAN: We would want to show it  
10 in the examples, how we would do this.

11 CHAIR STETKAR: You guys can sort of work  
12 this out among yourselves, I think.

13 (Laughter.)

14 MR. WACHOWIAK: There was nothing that I  
15 saw that was outside the scope of what we have in the  
16 document. The sensitivity is probably the more  
17 difficult of the ones to do, and we just need to see  
18 how we can do it within the scope of the project that  
19 we are working on. I think we understand your  
20 comments there. It is not the instructions for how  
21 you plug this into your fire PRA uncertainty analysis.  
22 It is a look at what would an analyst do to address  
23 parameter uncertainty, and I think we can provide some  
24 examples of that.

25 Anyway, so, we will talk about it amongst

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1 ourselves, but I didn't see any showstoppers. I agree  
2 with Mark.

3 MR. SALLEY: Again, I think that is the  
4 key. I don't think there's any showstoppers. This is  
5 a pretty good document. I will stand behind this  
6 document. It has been through the process.

7 We will make the changes. We will bring  
8 the team back together in the next couple of weeks,  
9 Dave, and have a few more meetings, do some of the  
10 things we talked about.

11 And again, we want to request a letter  
12 from you, John, to go forward and publish this.

13 CHAIR STETKAR: There's a couple of things  
14 I need to do before we wrap up.

15 MEMBER SHACK: When are you coming back to  
16 the full Committee?

17 CHAIR STETKAR: They are coming in May.

18 MR. SALLEY: May is what we were going  
19 for.

20 CHAIR STETKAR: And I want to talk about  
21 that. But there's a couple of other things I need to  
22 do here.

23 First of all, I have to ask this: are  
24 there any members of the public here who want to make  
25 any comments?

1 (No response.)

2 And I believe we have a bridge line open.

3 I have to give people --

4 MR. BROWN: The bridge is open.

5 CHAIR STETKAR: The bridge is open.

6 There's somebody out there. Excellent.

7 Is there anyone on the bridge line who  
8 would like to make any comments or statements or have  
9 any questions? Is there anybody out there? Say  
10 something so we know definitely it's open.

11 PARTICIPANT: Yes, I am out here. I can  
12 hear you guys. Can you hear me?

13 CHAIR STETKAR: Thank you. That's  
14 wonderful. Confirmation is good.

15 PARTICIPANT: Okay. I don't have any  
16 comments.

17 CHAIR STETKAR: Great. Thank you very  
18 much.

19 We will reclose the bridge line then, just  
20 so we are not disturbed.

21 And what I would like to do first is to go  
22 around the table and see if any of the members have  
23 any further comments or questions.

24 And then, Mark, what I would like to do is  
25 explore, do you still want to come in May.

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1 MR. SALLEY: Yes.

2 CHAIR STETKAR: Okay.

3 MR. SALLEY: Yes. And just to close out  
4 my slide there, John -- and I will turn it right back  
5 to you -- if you look at the time we have invested in  
6 this, there's other things that need to be done.  
7 Okay? We saw doing this, talking parameter  
8 uncertainties, that we need to catalog a lot of the  
9 parameters, the k-rho-Cs for different materials,  
10 things of that nature that the modelers are going to  
11 need. We would like to do that as a supplement to  
12 this.

13 The V&V, you brought up two excellent  
14 points. Since we have done that V&V, we have created  
15 new tools, you know, FLASH-CAT and THIEF being two of  
16 them. And we are going to make more. We need to go  
17 back to that V&V.

18 NIST has located a lot more experimental  
19 data out there that we can use to expand that V&V, and  
20 these are the kind of things that we want to do. One  
21 of the things with the experimental stuff, to answer  
22 a question earlier about the different labs, when we  
23 did the original V&V, you should have seen how many  
24 experiments we threw away. I mean, a lot of people  
25 gave us a lot of experiments, and we went through them

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1 and we started saying, "What's the quality of this?"  
2 And we couldn't trace quality back. It is like,  
3 "Sorry, we can't use it because you introduced too  
4 many uncertainties into our validation."

5 So, again, since that, in the spirit of  
6 working together, I know Kevin and Rick have spent a  
7 lot of time looking through a lot of other catalogs of  
8 experiments that we can bring in. The bottom line is  
9 we need to get over this hurdle to get back to the V&V  
10 and get on with it.

11 So, with that, John, I will turn it back  
12 to you.

13 CHAIR STETKAR: Okay. Let's go around the  
14 table, and I still want to make a couple of comments  
15 on what we see as the full Committee.

16 Bill, any comments? Any further  
17 questions?

18 Said?

19 MEMBER ABDEL-KHALIK: Well, I have sort of  
20 a big-picture comment. Looking at the incremental  
21 effort that an analyst would have to go through going  
22 from his own model to a CFD model, have you thought  
23 developing some kind of intermediate step between  
24 these two, where instead of having a two-zone, single-  
25 compartment model versus a detailed CFD model with

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1 thousands or tens of thousands of nodes, maybe coming  
2 up with a multi-zone, multi-compartment model where  
3 not all zones are the same? There are different types  
4 of zones that one can incorporate in sort of more of  
5 a macroscopic model.

6 MR. McGRATTAN: A zone model will have  
7 different conditions and different compartments.

8 MEMBER ABDEL-KHALIK: No, no, no. I  
9 understand. But within a single compartment you can  
10 have different types of zones.

11 MR. McGRATTAN: There is a model that was  
12 developed in Germany called COCOSYS. It was one of  
13 the models that was evaluated in this -- there was  
14 mention before of this benchmark exercise,  
15 international collaboration. The Germans had this  
16 model called COCOSYS.

17 It broke up a single compartment into a  
18 couple of dozen zones. But in my opinion the problem  
19 with that approach was that they never got beyond all  
20 of the questions and concerns that bedevil zone  
21 models.

22 Most of the people who participated in  
23 this said, well, if it takes an hour to run COCOSYS  
24 and a day to run a CFD model, that wasn't considered  
25 a big enough reason to develop this so-called hybrid

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1 model. That was just the impression, that it still  
2 had too many of the limitations of a zone model,  
3 because you didn't really have a true fluid, you know,  
4 a faithful fluid dynamics solver.

5 MEMBER ABDEL-KHALIK: It just seems to me  
6 that there is sort of almost a three-order-of-  
7 magnitude difference in amount of effort required for  
8 one model versus the other. And there has got to be  
9 some reasonable intermediate step that would give you  
10 enough resolution for what you need without having to  
11 make that amazing jump in common effort.

12 It seems worthwhile to at least explore.  
13 Because, you know, you can define a model in terms of  
14 volume elements and boundary elements, and they are  
15 not the same. You can build a model from a limited  
16 number of volume elements and boundary elements that  
17 would allow you to come up with enough resolution to  
18 understand what is going on.

19 MR. JOGLAR: In my opinion, that is the  
20 reason the zone models are still alive, because it was  
21 the bridge between the hand calc and the CFD. So, I  
22 understand your point.

23 CHAIR STETKAR: Any more?

24 MEMBER ABDEL-KHALIK: No.

25 CHAIR STETKAR: Dennis?

1                   MEMBER BLEY: Yes. In spite of maybe what  
2 it sounded like, I was really pleased reading this  
3 draft. I think you guys have done a heck of a job.  
4 I think the work on modeling uncertainty is really  
5 helpful.

6                   Many of the things I talked about I think  
7 could be addressed with some relatively-limited  
8 additional text to provide cautions and guidance and  
9 direction to folks.

10                   But congratulations. I think you have  
11 done a nice piece of work here.

12                   CHAIR STETKAR: Steve?

13                   MEMBER SCHULTZ: Yes, I just have one  
14 comment. That was that I was struck by the  
15 opportunity that you had and used to adopt comments,  
16 get comments and then adopt the comments through the  
17 workshop and training programs that have taken place  
18 recently in the last year, and used those as a part of  
19 document development. That certainly has been a great  
20 addition to improving not only the technical portion  
21 of the document, but the presentation of it. So that  
22 it comes forward as a very understandable and user  
23 document that has some strength of practice and  
24 purpose behind it.

25                   So, I was pleased to see that and

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1 certainly would encourage that in documents that are  
2 associated with user documents in the future. I think  
3 this is an excellent example of how one develops a  
4 document for the user, by bringing it forward to the  
5 training program and gaining from the experience of  
6 the user in finalizing the documentation. So, that  
7 has been a great help here.

8 Other than that, John, no further  
9 comments.

10 CHAIR STETKAR: Thank you.

11 I would also like to say I think this is  
12 a really good document. I do think, and echo Dennis,  
13 I do think it needs a bit of work in a couple of  
14 areas. We have mentioned those. I will summarize them.

15 I think a little bit better guidance about  
16 what to do when your scenario exceeds the V&V bounds.  
17 We talked quite a bit about that.

18 And some treatment of parameter  
19 uncertainty and guidance about how one might do that  
20 within the regimes of the three different categories  
21 of models.

22 But, other than that, I would echo, I  
23 think the modeling uncertainty is really good. I  
24 think that the practical examples and qualitative  
25 guidance that you have in there for a user on

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1 decisions about what types of models to use and  
2 limitations, I think it is really, really good.

3 Mark, the only thing I would say as far as  
4 the full Committee meeting --

5 MEMBER SHACK: Plus your spurious  
6 actuation question.

7 CHAIR STETKAR: Oh, yes. I'm sorry.  
8 Thank you.

9 (Laughter.)

10 I ranted long enough. I figured they  
11 picked that up from that section on multiple spurious  
12 operations. But that also, that is text-writing. It  
13 isn't fundamental technology. It is just  
14 acknowledging how that is treated in the risk-informed  
15 world, instead of just the deterministic focus.

16 And change the sign in that one equation.

17 MEMBER SHACK: Parameter uncertainty, I  
18 mean, sometimes that is sort of dictated by the  
19 guidance that you have. I mean, if it says use the  
20 98th percentile, you use the 98th percentile.

21 CHAIR STETKAR: That being said, and,  
22 indeed, most of the deterministic -- either the  
23 deterministic uses of the firewalls, and they are used  
24 in the deterministic analyses, pretty much say that,  
25 and the screening guidance for using fire models says,

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1 as a way of screening out areas or fire scenarios for  
2 further evaluation, and the risk-informed does that.

3 But a lot of the people in NFPA 805  
4 applications are going to be plucking mean values,  
5 running some sort of fire model, mean values from the  
6 parameter uncertainty distributions, running the fire  
7 models, whether algebraic or zone models, anyway, and  
8 presenting the results as, "Here is my answer."

9 And they are doing that. They have done  
10 that in the pilot studies. They are doing that in --

11 MEMBER SHACK: They always do it.

12 CHAIR STETKAR: And the thorniest issues  
13 are going to be handled that way. So, I think that  
14 the parameter uncertainty is a relevant topic for the  
15 things that survived into what the NRR folks are going  
16 to be reviewing.

17 One thing I did want to mention, Mark, is  
18 for the full Committee meeting I am presuming that,  
19 given the timing because you are on the schedule for  
20 May, that what the full Committee will be reviewing  
21 will be the document that we have. Is that correct?  
22 Or are you planning to change it?

23 MR. SALLEY: I'm planning to change it.  
24 I hope my team is behind me with that.

25 CHAIR STETKAR: Well, if you change it,

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1 recognize that today is March 21st --

2 MR. SALLEY: Right.

3 CHAIR STETKAR: -- and we need that  
4 document 30 days before our full Committee meeting.

5 MR. SALLEY: Okay.

6 CHAIR STETKAR: So, you don't have much  
7 time to make the changes.

8 MR. SALLEY: When is the May meeting?

9 MR. LAI: May 11th.

10 MR. SALLEY: April 11th?

11 MR. LAI: May 11th. So, you need to get  
12 it to me by April 11th.

13 CHAIR STETKAR: Just keep that in mind  
14 because we do need that 30-day lead time. We don't  
15 want to get into the situation where we are discussing  
16 something that is a moving target at the time of the  
17 meeting.

18 MR. SALLEY: I want to give you the final  
19 document, John.

20 CHAIR STETKAR: Yes. Okay.

21 MR. SALLEY: And then, that is what the  
22 team will strive to do. Then, I think we are going to  
23 focus-in on that and try to deliver that to you.

24 MEMBER ABDEL-KHALIK: Can we get a copy  
25 with track-changes anyway? So that those of us who

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1 sort of sludged through this would not have to go  
2 through the whole thing hunting for changes?

3 MR. SALLEY: If that would help you, we  
4 would be happy to do it.

5 CHAIR STETKAR: Just work with John and  
6 make sure.

7 The only message I wanted to get across is  
8 that, if we have that May meeting, I don't want to be  
9 in a situation to say, "Well, we're still finishing up  
10 a few paragraphs in section" whatever.

11 MR. SALLEY: These are the fire modelers,  
12 not the HRA group.

13 (Laughter.)

14 CHAIR STETKAR: That is on the record.

15 (Laughter.)

16 That being said, I would like to thank the  
17 staff and everyone.

18 I thought that it was a really good  
19 presentation. I think we had a good exchange. I  
20 think there is a clear path to getting this thing out  
21 in a timely manner.

22 With that, we are adjourned.

23 (Whereupon, at 5:24 p.m., the meeting was  
24 adjourned.)

25



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## **NUREG-1934/EPRI 1023259**

# **Nuclear Power Plant Fire Modeling Application Guide**

ACRS Reliability & PRA Subcommittee

March 21, 2012

Mark Henry Salley, NRC/RES

Rick Wachowiak, EPRI



**Office of Nuclear  
Regulatory Research**



*Fire Research  
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# Purpose of the Meeting

- NRC and EPRI have completed the project:
  - Discuss the report with the Subcommittee
  - Discuss Stakeholder Involvement
  - Discuss need & use of the report
  - Discuss future work in Fire Modeling Program
- Request a Letter from the ACRS

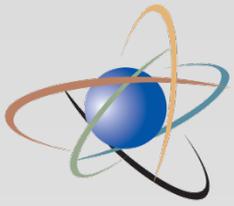
# Short History of Fire Modeling in US NPPs

- 1960/70s BTUs/Sq. Ft. for Fire Areas
- 1980 Statements for Consideration for new Rule Appendix R
- 1981-85 UCLA “COMPBRN” (NUREG/CR-2269,3239,4566)
- 1991 Individual Plant Examination of External Events (IPEEE) for Severe Accident Vulnerabilities (Generic Letter 88-20, Supplement 4)
- 2000 Fire Protection Significance Determination Process (SDP) as a part of Reactor Oversight Program (ROP)
- 2001 NFPA 805 issued
- 2004 NRC amends 10 CFR 50.48(c) Fire Protection
- 2004 Fire Dynamics for Inspectors is published (NUREG-1805)
- 2005 Fire PRA Method published (NUREG/CR-6850 EPRI-1011989)
- 2007 Fire Model Verification and Validation report published (NUREG-1824 EPRI-1011999)
- 2008 Fire Model Phenomena Identification and Ranking Table (PIRT) completed (NUREG/CR-6978)
- 2012 Fire Modeling Application Guide completed (NUREG-1934 EPRI 1023259)

- NRC/EPRI Memorandum of Understanding
  - Fire Research Addendum
  - Provides for Joint Publication
- Team Composition
  - NRC Experts
  - Industry Experts
    - NSSS Vendors
    - Consultants
  - National Institute of Standards & Technology
  - Universities

# Project History

- 2006 ACRS Subcommittee recommends Fire Model Users Guide to support the Fire Model V&V project
- 2009 First Draft Fire Modeling Application Guide Complete and select review
- 2010 Draft issued Public Comment
- 2011 Second Draft issued Public Comment
- 2011 Second Draft piloted in Fire PRA Training program
- 2012 Final Report Complete



# Today's Presentations

- David Stroup
  - Overview & Fire Modeling Process
- Francisco Joglar
  - Fire Model Selection & Implementation
- Kevin McGrattan
  - Uncertainty & Applicability
- Team Presentation
  - Fire Modeling Examples



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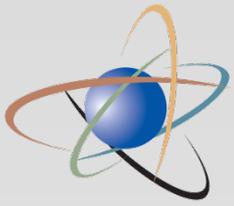
## Chapter 1 - Introduction

## Chapter 2 - Fire Modeling Process

David Stroup, NRC/RES

 **Office of Nuclear  
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# Purpose of Report

- Focused on User
- Not a Replacement for Model User's Guide
- Practical Applications
- Training
- Quantify Uncertainty

# ACRS

## Recommendations

- NFPA 805
- NUREG-1824/EPRI 1011999 Review
- User's/Application Guide Needed
- Estimates of Ranges of Parameters
- Quantitative Estimates of Uncertainty

- Two Rounds of Public Comments
  - Treatment of Uncertainty Needed Clarification
  - Consistency
    - Within the main chapters
    - Within the chapters and the examples/appendices
    - Within individual examples/appendices
  - Application of Verification and Validation Ranges

- Background Information
- User Capabilities
- Basic Theory
- Report Organization and Objectives

## Fire Modeling Process:

- 1) define goals and objectives
- 2) characterize the fire scenarios
- 3) select fire models
- 4) calculate fire-generated conditions
- 5) conduct sensitivity and uncertainty analyses
- 6) document the analysis



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## Chapter 3

# Guidance on Fire Model Selection and Implementation

Francisco Joglar, HAI

 **Office of Nuclear  
Regulatory Research**



# Introduction

Chapter 3 provides guidance and recommendations for modeling fire scenarios for typical nuclear industry applications:

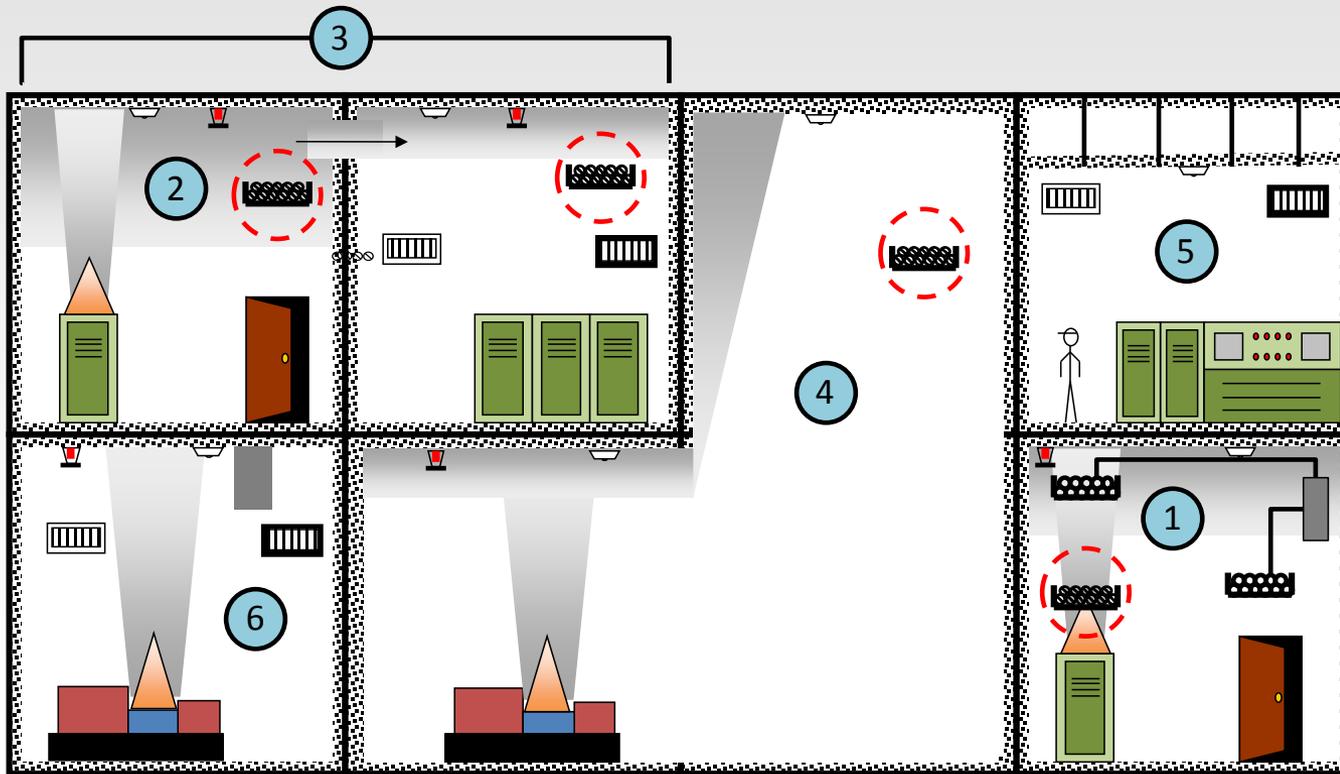
- NFPA 805
- Fire Probabilistic Risk Assessments

# Scope

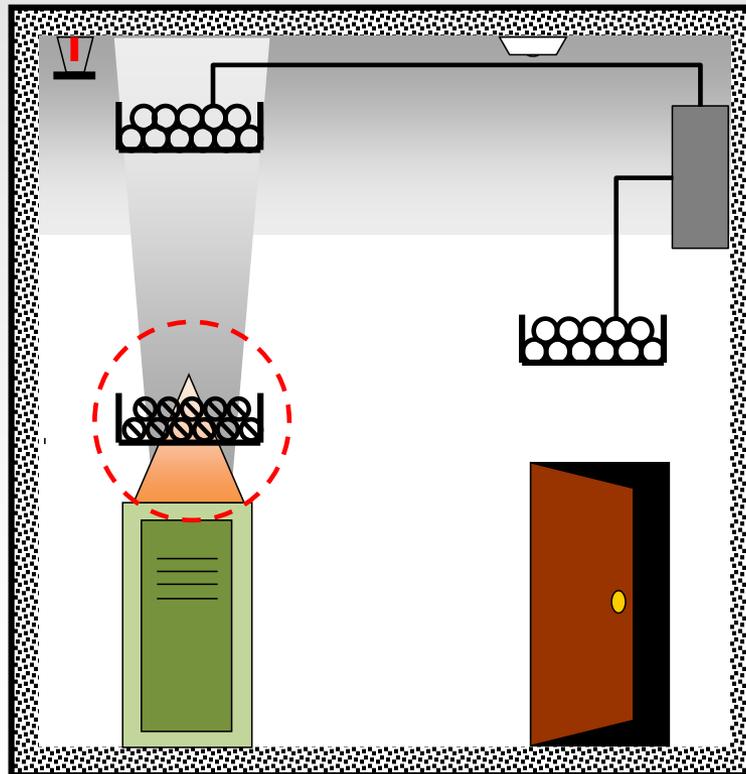
- Qualitatively covers the following technical elements:
  - Heat Release Rate
  - Plant Area Configuration
  - Ventilation Effects
  - Targets
  - Intervening Combustibles

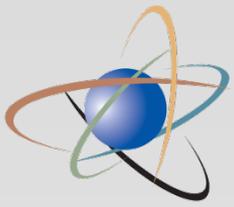
# Scope

Figure 3-1. Pictorial representation of fire scenarios.



## Scenario 1: Targets in the Flames or Plume

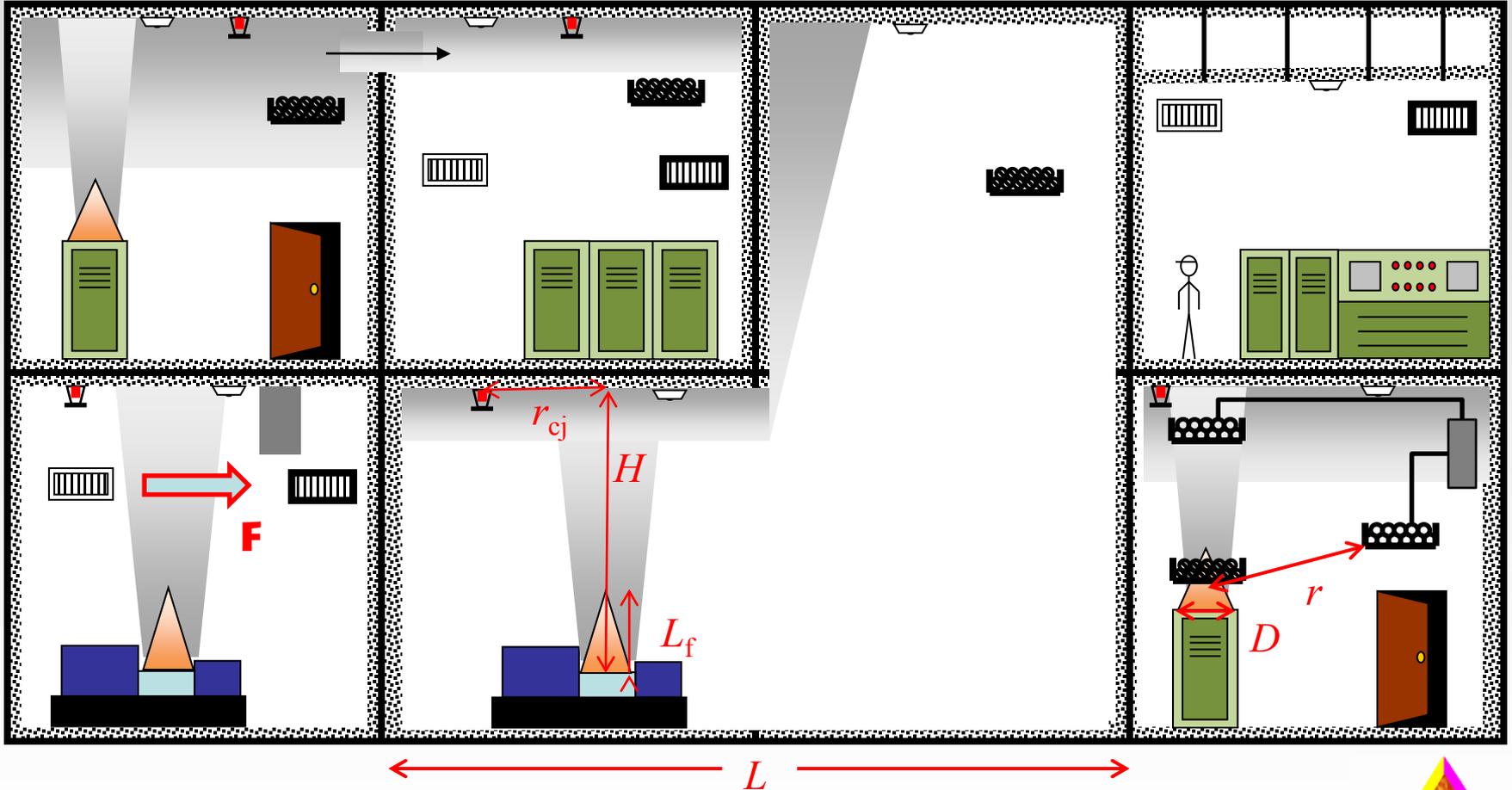




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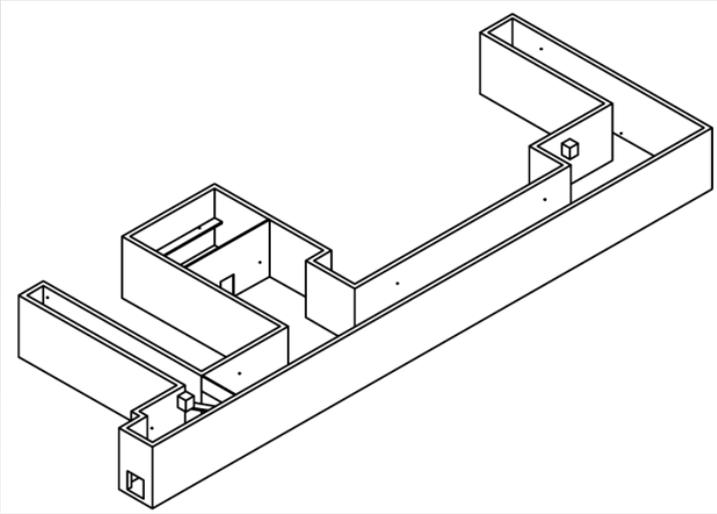
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# What to do if the scenario is out of the validation range?

1. Sensitivity Analysis – Perform a calculation for a similar scenario that is more severe yet in range.
2. Reference other validation studies performed by model developers or others (i.e. universities, professional societies)

# Example of Sensitivity Analysis



Problem: The corridor length to ceiling height ratio (L/H) is outside of validation range.

Solution: Redo calculation (or apply a simple correlation) to determine if a similar (yet more challenging) scenario increases the probability of failure.

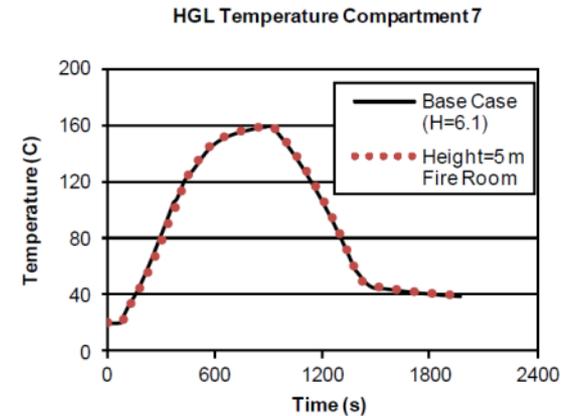
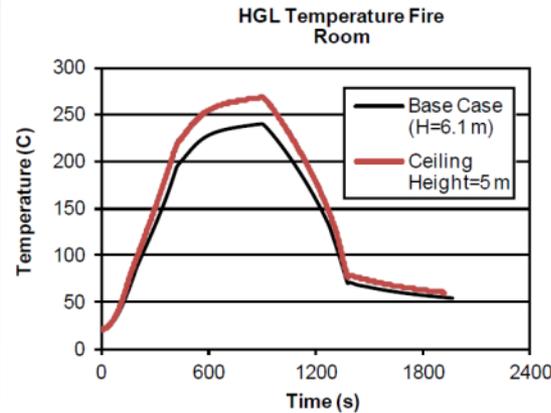


Figure G-10. Hot Gas Layer Temperature for Reduced Ceiling Height by MAGIC.

# Summary

The material in this chapter covers:

- Scenario objectives
- Modeling Strategy
- Recommended models
- Reference to detailed examples in the appendices



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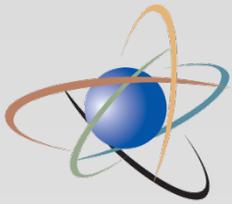
## Model Uncertainty

Kevin McGrattan

National Institute of Standards and Technology

 **Office of Nuclear  
Regulatory Research** 

  
*Fire Research  
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# ACRS Review of NUREG-1824



UNITED STATES  
NUCLEAR REGULATORY COMMISSION  
ADVISORY COMMITTEE ON REACTOR SAFEGUARDS  
WASHINGTON, DC 20555-0001

ACRSR-2219

October 25, 2006

Mr. Luis Reyes  
Executive Director for Operations  
U.S. Nuclear Regulatory Commission  
Washington DC 20555-0001

SUBJECT: DRAFT FINAL NUREG-1824, "VERIFICATION AND VALIDATION OF  
SELECTED FIRE MODELS FOR NUCLEAR POWER PLANT APPLICATIONS"

Dear Mr. Reyes:

During the 536<sup>th</sup> meeting of the Advisory Committee on Reactor Safeguards, October 4-6, 2006, we met with representatives of the NRC staff, Electric Power Research Institute (EPRI), and the National Institute of Standards and Technology (NIST) to discuss the draft final NUREG-1824 (EPRI 1011999), "Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications." Our Subcommittee on Reliability and Probabilistic Risk Assessment (PRA) also reviewed this matter during its meeting on September 21, 2006. During our review, we had the benefit of the documents referenced.

#### CONCLUSION AND RECOMMENDATIONS

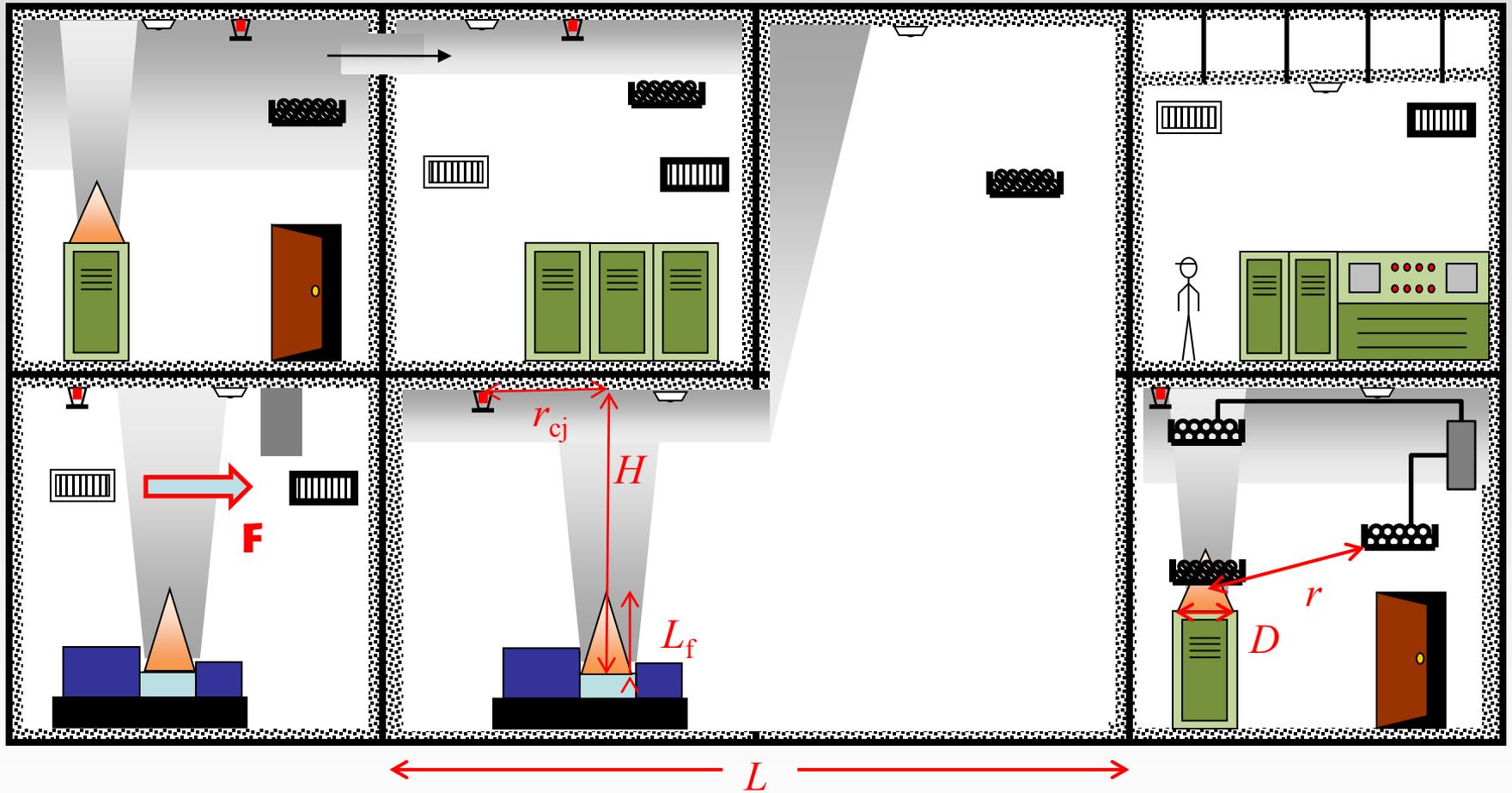
1. The report provides a systematic evaluation of the predictive capability of five commonly used compartment fire models. It should be published.
2. The user's guide to be developed by the staff should include:
  - a. Estimates of the ranges of normalized parameters to be expected in nuclear plant applications.
  - b. Quantitative estimates of the uncertainties associated with each model's predictions, preferably in the form of probability distributions.

#### BACKGROUND

Fire models are used in a number of safety evaluations, including fire risk analysis; demonstrating compliance with, and exemptions to, the regulatory requirements for fire protection in 10 CFR Part 50, Appendix R; the significance determination process of the Reactor Oversight Process; and establishing the risk-informed, performance-based voluntary

A user will have to determine whether the results of the verification and validation study are applicable to the situation to be analyzed. This is done using "normalized parameters" ... that allow users to compare results from scenarios of different scales by normalizing physical characteristics of the scenario. These normalized parameters are traditionally used in fire modeling applications and are included in the NUREG report. **The user's guide should provide estimates of the ranges of normalized parameters to be expected in nuclear plant applications.** These estimates would allow a determination of whether risk-significant fires fall within or outside the parameter ranges covered by the verification and validation process.

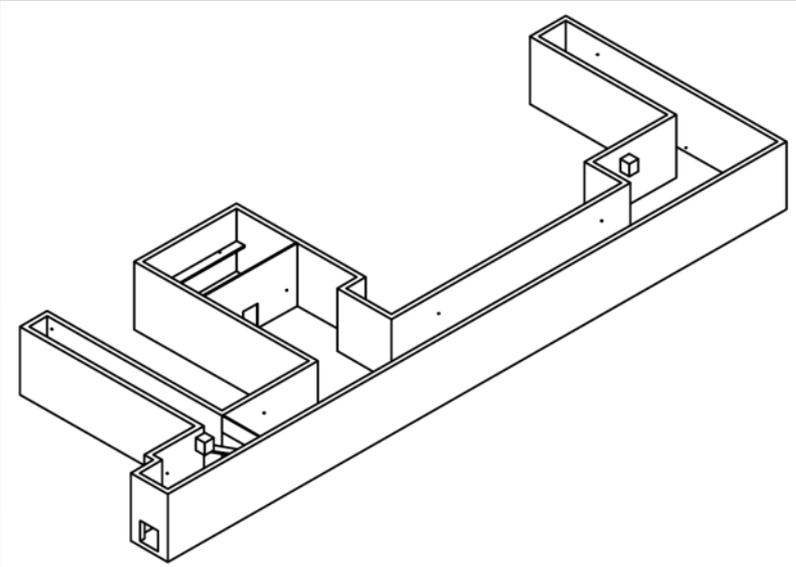
# How the Non-Dimensionalized Parameters are Applied



# What to do if the scenario is out of the validation range?

1. Sensitivity Analysis – Perform a calculation for a similar scenario that is more severe yet in range.
2. Reference other validation studies performed by model developers or others (i.e. universities, professional societies)

# Example of Sensitivity Analysis



Problem: The corridor length to ceiling height ratio ( $L/H$ ) is outside of validation range.

Solution: Redo calculation (or apply a simple correlation) to determine if a similar (yet more challenging) scenario increases the probability of failure.

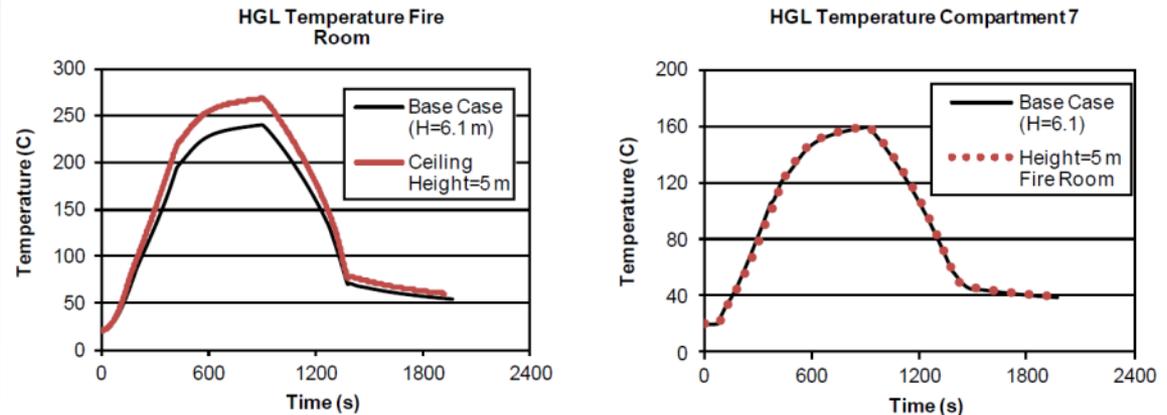
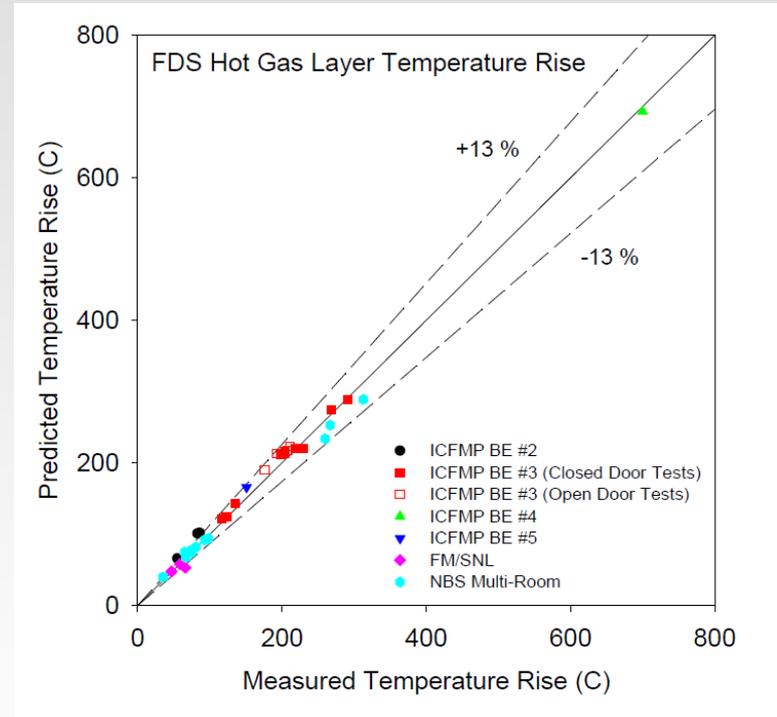
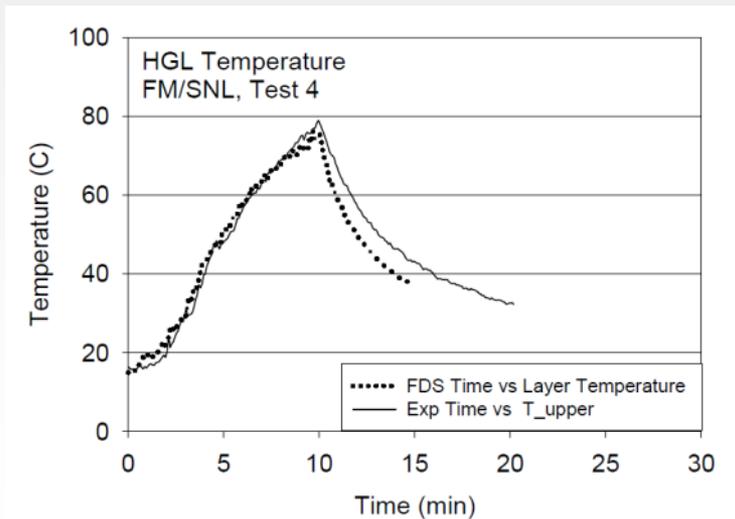
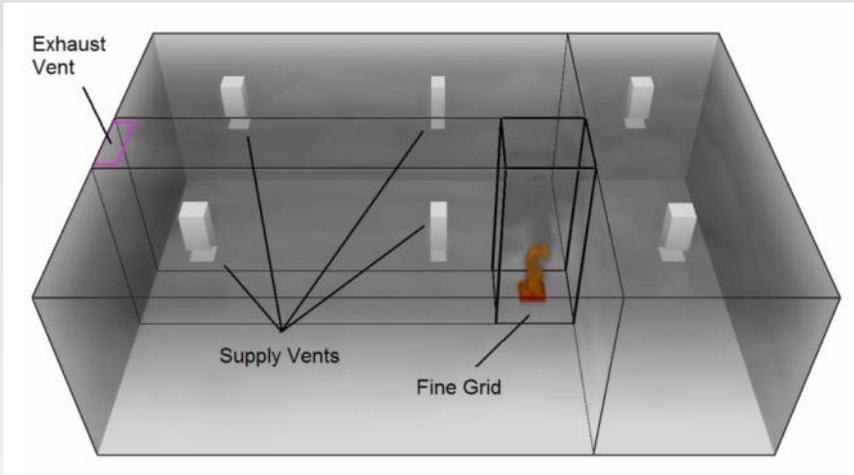


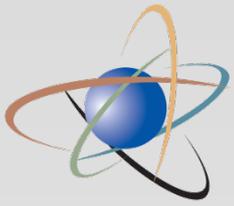
Figure G-10. Hot Gas Layer Temperature for Reduced Ceiling Height by MAGIC.

## Types of Epistemic Uncertainty (NUREG-1855)

- Parameter Uncertainty – refers to the contribution of the uncertainty in the input parameters to the total uncertainty of the simulation
- Model Uncertainty – refers to the effect of the model assumptions, simplified physics, numerics, etc.
- Completeness Uncertainty – refers to physics that are left out of the model. For most, this is a form of Model Uncertainty.

# Fire Model Validation Study, NUREG-1824





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# Summary of NUREG-1824 V&V Study

NUREG-1824      EPRI 1011999  
Final Report

---

## Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications

**Volume 1:  
Main Report**

U.S. Nuclear Regulatory Commission  
Office of Nuclear Regulatory Research  
Washington, DC 20555-0001



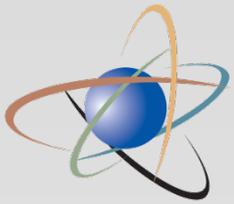
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**Table 3-1: Results of the Validation & Verification of the Selected Fire Models for Nuclear Power Plant Fire Modeling Applications**

Parameter <sup>5</sup>		Fire Model				
		FDT <sup>5</sup>	FIVE-Rev1	CFAST	MAGIC	FDS
Hot gas layer temperature ("upper layer temperature")	Room of Origin	YELLOW+	YELLOW+	GREEN	GREEN	GREEN
	Adjacent Room	N/A	N/A	YELLOW	YELLOW+	GREEN
Hot gas layer height ("layer interface height")		N/A	N/A	GREEN	GREEN	GREEN
Ceiling jet temperature ("target/gas temperature")		N/A	YELLOW+ <sup>2</sup>	YELLOW+	GREEN	GREEN
Plume temperature		YELLOW-	YELLOW+ <sup>2</sup>	N/A	GREEN	YELLOW
Flame height <sup>3</sup>		GREEN	GREEN	GREEN	GREEN	YELLOW <sup>1</sup>
Oxygen concentration		N/A	N/A	GREEN	YELLOW	GREEN
Smoke concentration		N/A	N/A	YELLOW	YELLOW	YELLOW
Room pressure <sup>4</sup>		N/A	N/A	GREEN	GREEN	GREEN
Target temperature		N/A	N/A	YELLOW	YELLOW	YELLOW
Radiant heat flux		YELLOW	YELLOW	YELLOW	YELLOW	YELLOW
Total heat flux		N/A	N/A	YELLOW	YELLOW	YELLOW
Wall temperature		N/A	N/A	YELLOW	YELLOW	YELLOW

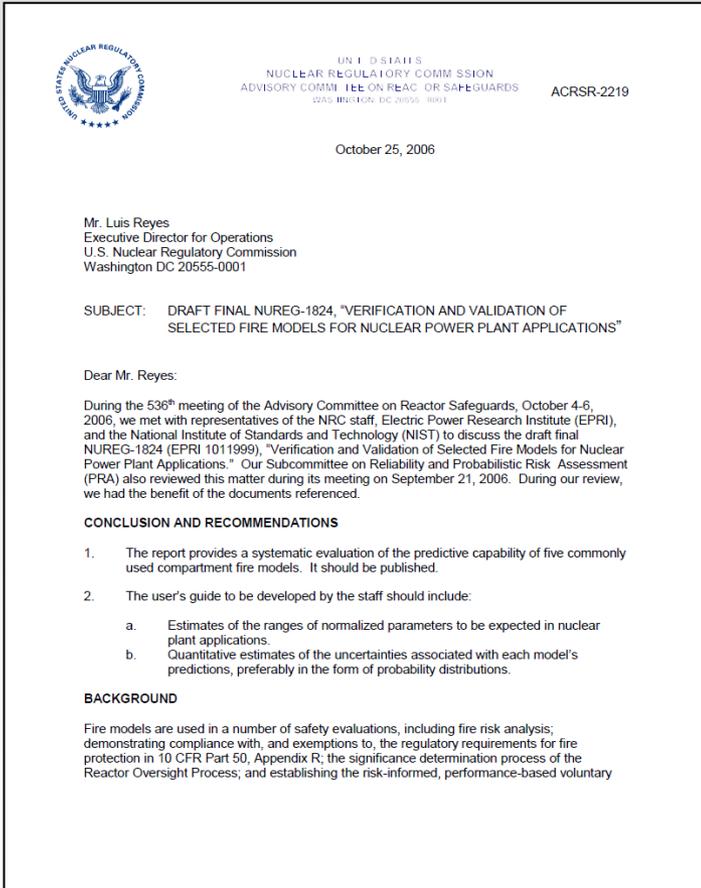




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# ACRS Review of NUREG-1824



The user's guide should also provide probability distributions for the model predictions due to the intrinsic model uncertainty, i.e., the uncertainty associated with the model's physical and mathematical assumptions. These distributions should not include the uncertainties in the heat release rate since the latter will be an input specified by the user. **The color designations provide no quantitative estimate of the intrinsic uncertainty.** This uncertainty is an important input in risk-informed applications. Even in non-risk-informed applications, a quantitative assessment of the tendency of a model to over- or under-predict would be valuable. The staff told us that such quantitative estimates will be provided in the user's guide. We look forward to reviewing this document.

# Improved Model Uncertainty Metrics

Table 4-1. Results of the V&V study, NUREG-1824 (EPRI 1011999).

Output Quantity	FDTs		FIVE		CFAST		MAGIC		FDS		Exp
	$\delta$	$\tilde{\sigma}_M$	$\tilde{\sigma}_E$								
HGL Temperature Rise*	1.44	0.25	1.56	0.32	1.06	0.12	1.01	0.07	1.03	0.07	0.07
HGL Depth*	N/A		N/A		1.04	0.14	1.12	0.21	0.99	0.07	0.07
Ceiling Jet Temp. Rise	N/A		1.84	<u>0.29</u>	1.15	<u>0.24</u>	1.01	0.08	1.04	0.08	0.08
Plume Temperature Rise	0.73	<u>0.24</u>	0.94	<u>0.49</u>	1.25	0.28	1.01	0.07	1.15	<u>0.11</u>	0.07
Flame Height**	I.D.	I.D.	I.D.								
Oxygen Concentration	N/A		N/A		0.91	<u>0.15</u>	0.90	0.18	1.08	0.14	0.05
Smoke Concentration	N/A		N/A		2.65	<u>0.63</u>	2.06	<u>0.53</u>	2.70	<u>0.55</u>	0.17
Room Pressure Rise	N/A		N/A		1.13	0.37	0.94	0.39	0.95	0.51	0.20
Target Temperature Rise	N/A		N/A		1.00	0.27	1.19	0.27	1.02	0.13	0.07
Radiant Heat Flux	2.02	<u>0.59</u>	1.42	0.55	1.32	0.54	1.07	0.36	1.10	0.17	0.10
Total Heat Flux	N/A		N/A		0.81	0.47	1.18	0.35	0.85	0.22	0.10
Wall Temperature Rise	N/A		N/A		1.25	0.48	1.38	0.45	1.13	0.20	0.07
Wall Heat Flux	N/A		N/A		1.05	0.43	1.09	0.34	1.04	0.21	0.10

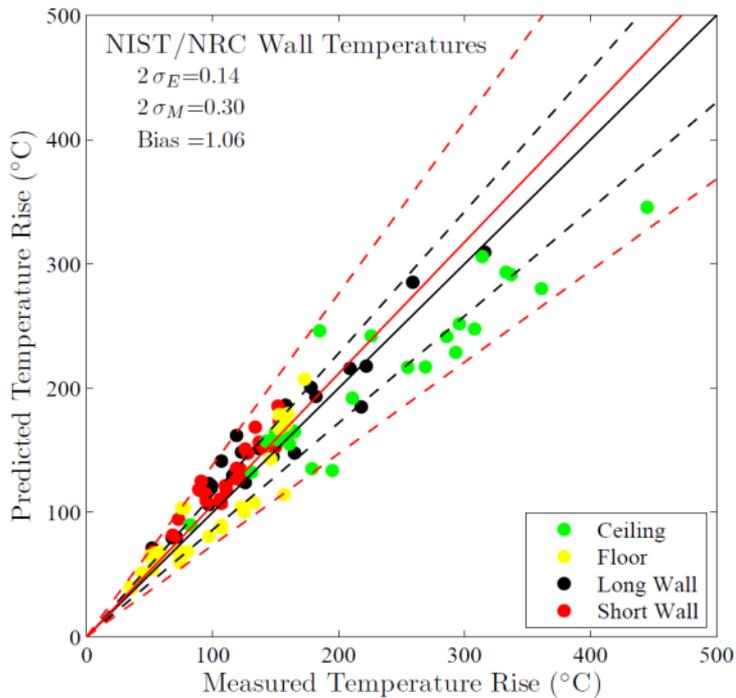
I.D. indicates insufficient data for the statistical analysis.

N/A indicates that the model does not have an algorithm to compute the given Output Quantity.

Underlined values indicate that the data failed a normality test because of the relatively small sample size.

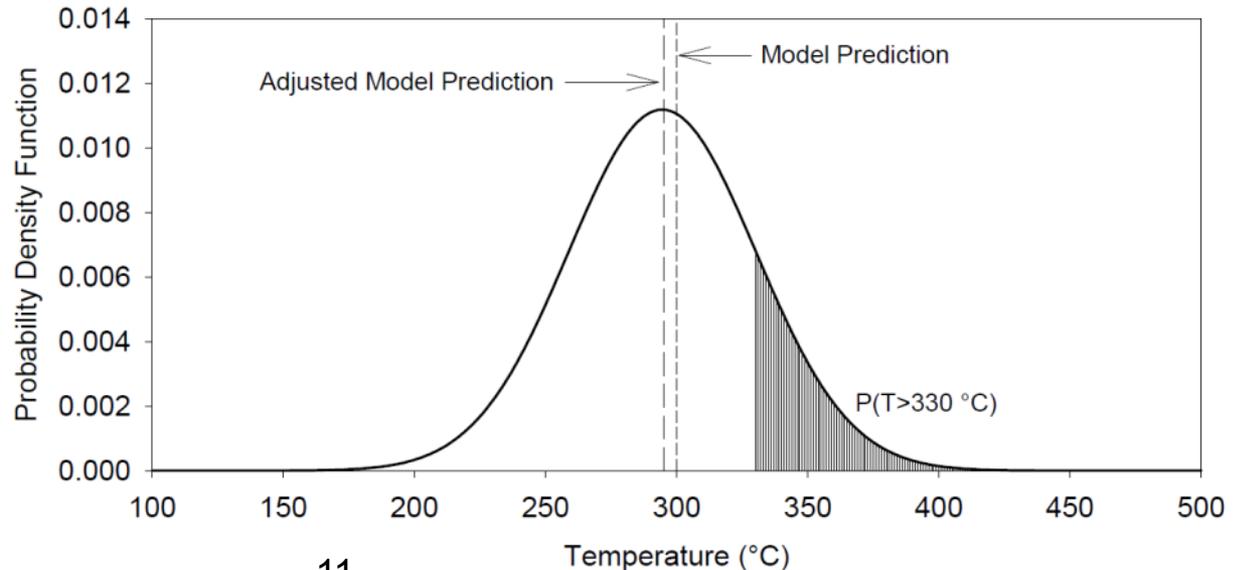
\* The algorithm used to compute the layer temperature and depth for the model FDS is described in NUREG-1824.

\*\* All of the models except FDS use the Heskestad Flame Height Correlation (Heskestad, *SFPE Handbook*). These models were shown to be in qualitative agreement with the experimental observations, but there was not enough data to further quantify this assessment.



(Left) Typical results from a validation study. The black lines indicate the experimental uncertainty and the red lines indicate the model uncertainty.

(Below) Given a model prediction of 300 °C, what is the probability that the actual temperature might exceed 330 °C, the failure temperature of the given target?



# Procedure for Calculating Model Uncertainty

Critical Value

$$P(x > x_c) = \frac{1}{2} \operatorname{erfc} \left( \frac{x_c - \mu}{\sigma\sqrt{2}} \right)$$

Model Prediction

$$\mu = M/\delta$$

Model Bias

$$\sigma = \tilde{\sigma}_M(M/\delta)$$

Model Standard Deviation

# How Model Uncertainty is Applied

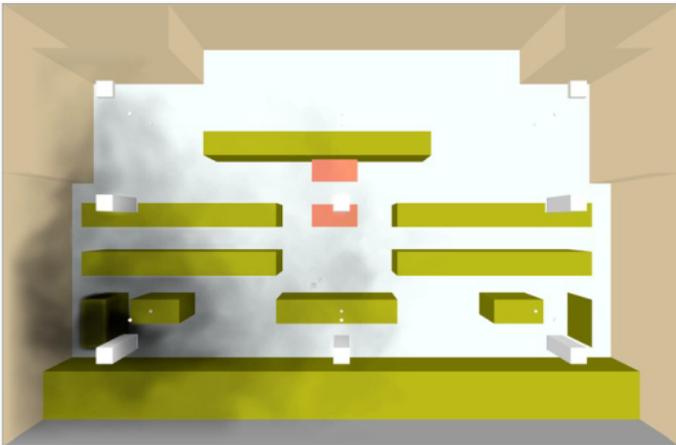
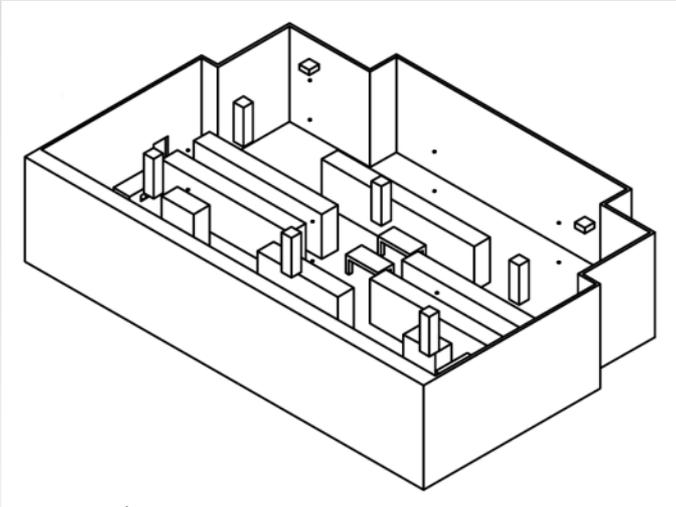


Table A-4. Summary of the model predictions of the MCR scenario.

Model	Bias Factor, $\delta$	Standard Deviation, $\tilde{\sigma}_M$	Ventilation	Predicted Value	Critical Value	Probability of Exceeding
<b>Temperature (<math>^{\circ}\text{C}</math>), Initial Value = 20 <math>^{\circ}\text{C}</math></b>						
FIVE (FPA)	1.56	0.32	Purge	70	95	0.000
CFAST	1.06	0.12		60	95	0.000
FDS	1.03	0.07		48	95	0.000
CFAST	1.06	0.12	No Vent.	82	95	0.009
FDS	1.03	0.07		70	95	0.000
<b>Heat Flux (<math>\text{kW}/\text{m}^2</math>)</b>						
FIVE	1.42	0.55	Purge	0.4	1	0.000
CFAST	0.81	0.47		0.1	1	0.000
FDS	0.85	0.22		0.2	1	0.000
CFAST	0.81	0.47	No Vent.	0.6	1	0.228
FDS	0.85	0.22		0.4	1	0.000
<b>Optical Density (<math>\text{m}^{-1}</math>)</b>						
CFAST	2.65	0.63	Purge	6.5	3	0.362
FDS	2.7	0.55		0.5	3	0.000
CFAST	2.65	0.63	No Vent.	47	3	0.906
FDS	2.7	0.55		31	3	0.909

# Back-up Slides

# Sensitivity Analysis to Address Parameter Uncertainty

Example: A well-known correlation in fire science indicates that the Hot Gas Layer (HGL) temperature rise,  $T - T_0$ , is proportional to the Heat Release Rate,  $\dot{Q}$ , to the two-thirds power:

$$T - T_0 = C \dot{Q}^{2/3}$$

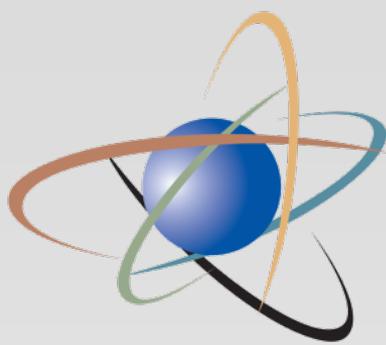
This means that the relative change in the HGL temperature is approximately two-thirds the relative change in the HRR:

$$\frac{\Delta T}{T - T_0} \approx \frac{2}{3} \frac{\Delta \dot{Q}}{\dot{Q}}$$

# Typical Power Relationships for Inputs/Outputs

Table 4-3. Sensitivity of model outputs from Volume 2 of NUREG-1824 (EPRI 1011999).

Output Quantity	Important Input Parameters	Power Dependence
HGL Temperature	HRR Surface Area Wall Conductivity Ventilation Rate Door Height	$2/3$ $-1/3$ $-1/3$ $-1/3$ $-1/6$
HGL Depth	Door Height	1
Gas Concentration	HRR Production Rate	$1/2$ 1
Smoke Concentration	HRR Soot Yield	1 1
Pressure	HRR Leakage Rate Ventilation Rate	2 2 2
Heat Flux	HRR	$4/3$
Surface/Target Temperature	HRR	$2/3$



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## Appendices

Francisco Joglar

Kevin McGrattan



**Office of Nuclear  
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*Fire Research  
Branch* 

# Example Applications

- Eight example applications, each documented in an individual appendix
  - Based on typical fire scenarios in NPP's
  - Serve as a template for consistency in the analysis and documentation of fire modeling calculations
  - Consider the fire modeling requirements of NFPA 805
  - Cover the routinely used capabilities of the fire models

## A. Cabinet Fire in the Main Control Room

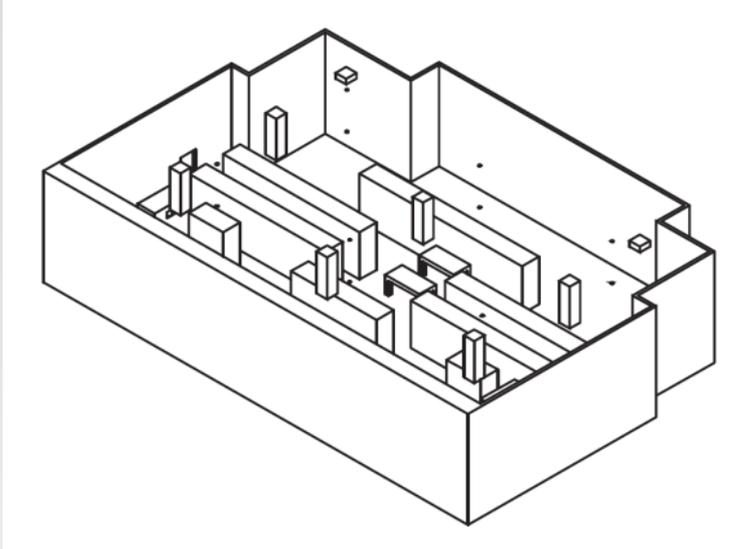


Figure A-11. FDS/Smokeview rendering of the MCR, as viewed from above.

## B. Cabinet Fire in a Switchgear Room

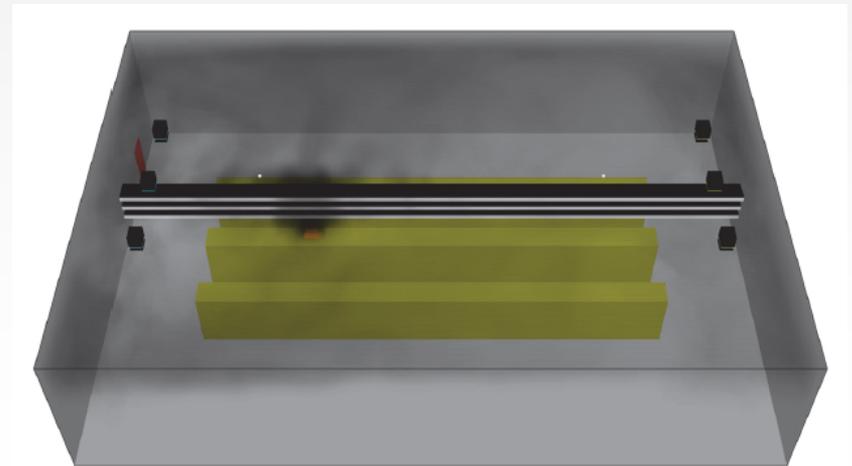
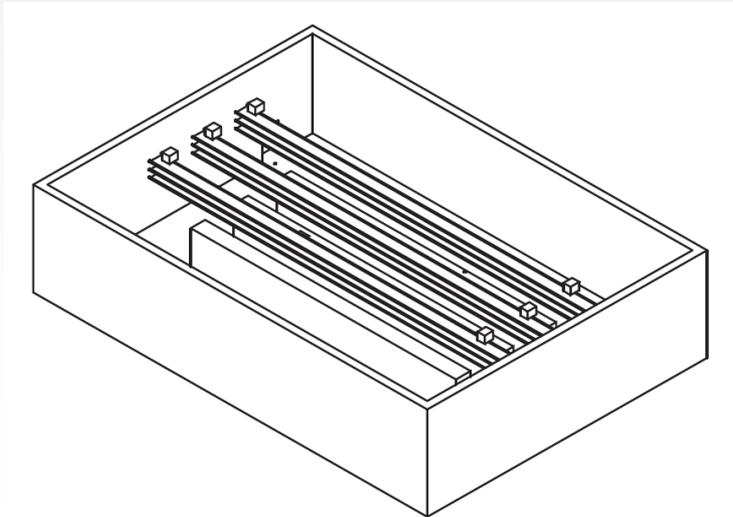
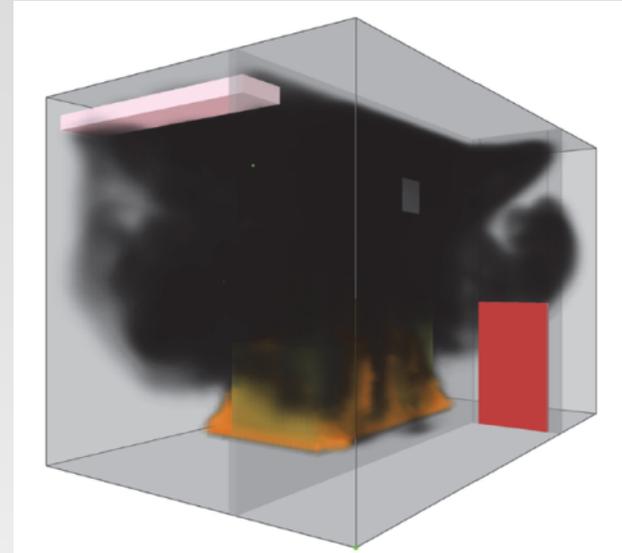
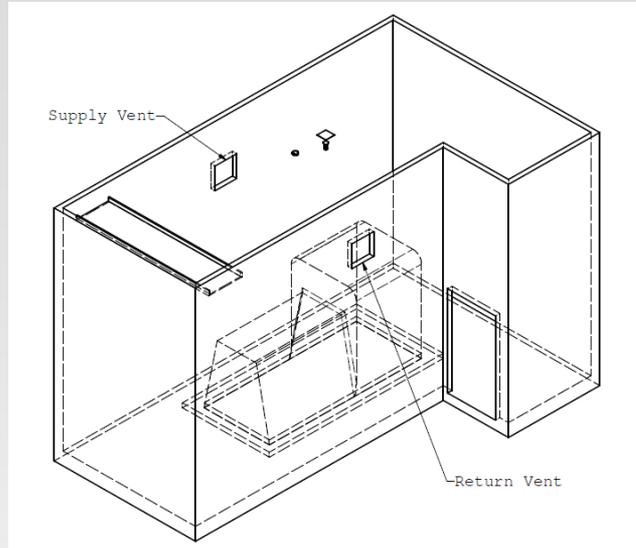
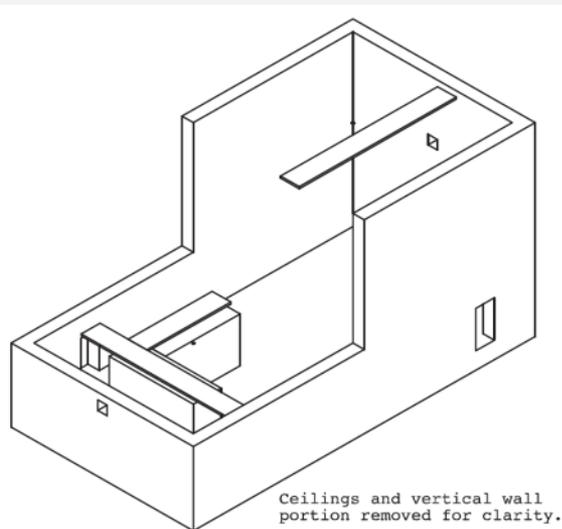


Figure B-10. FDS/Smokeview rendering of the switchgear room.

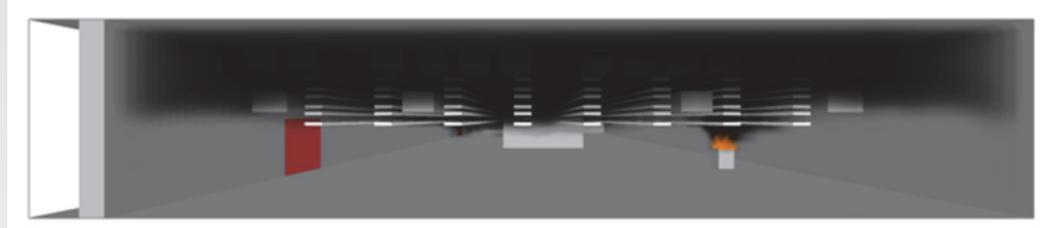
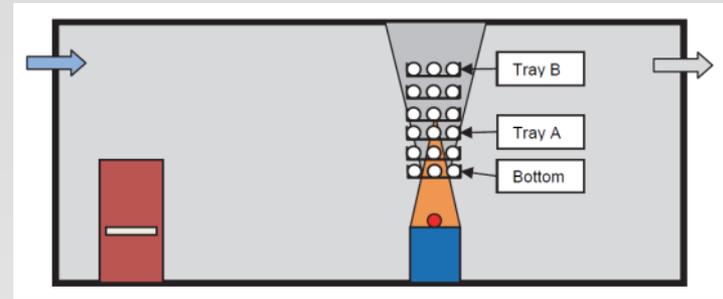
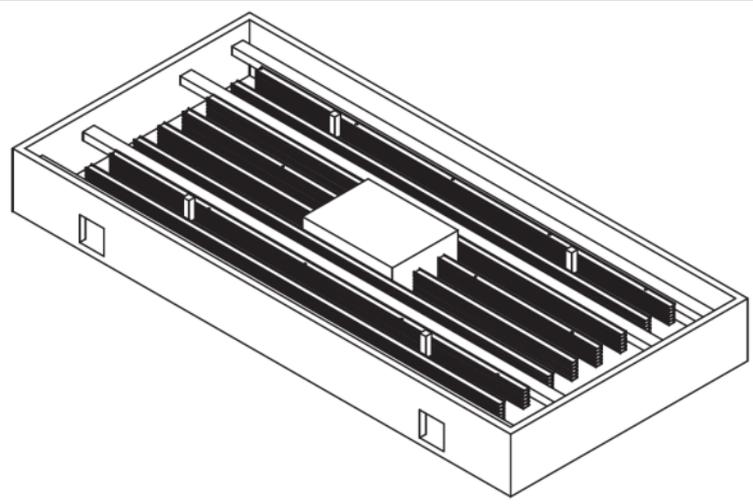
## C. Lube Oil Fire in a Pump Room



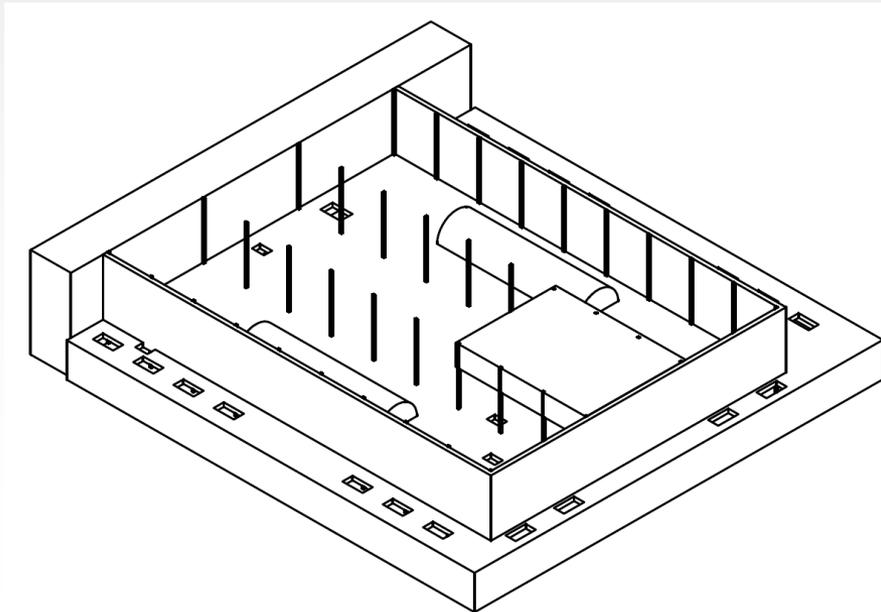
## D. Motor Control Fire in a Switchgear Room



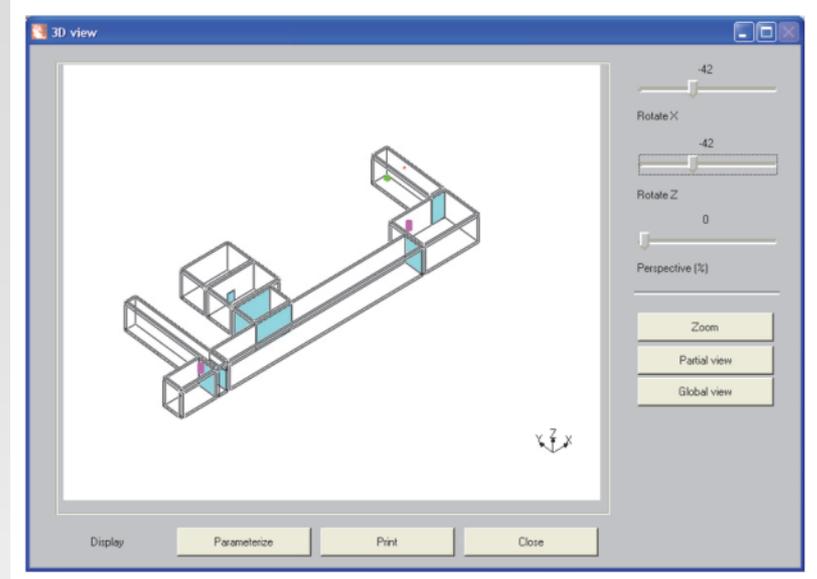
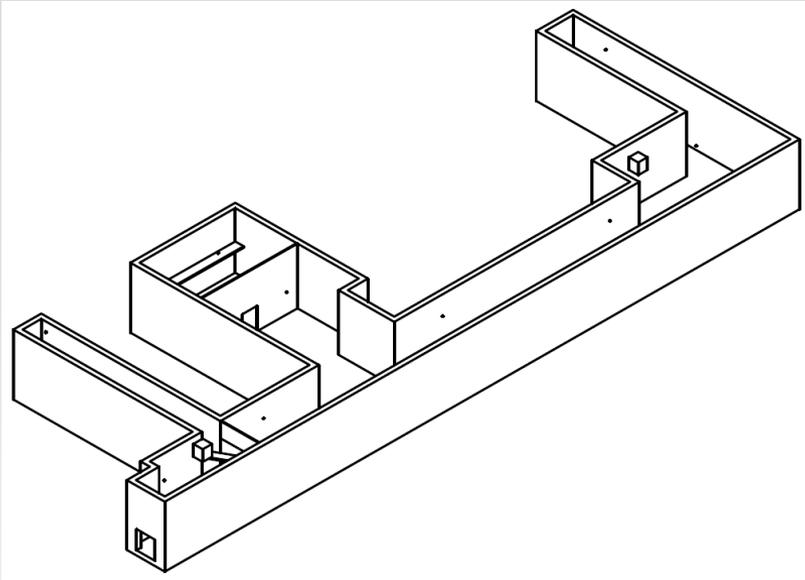
## E. Transient Fire in a Cable Spreading Room



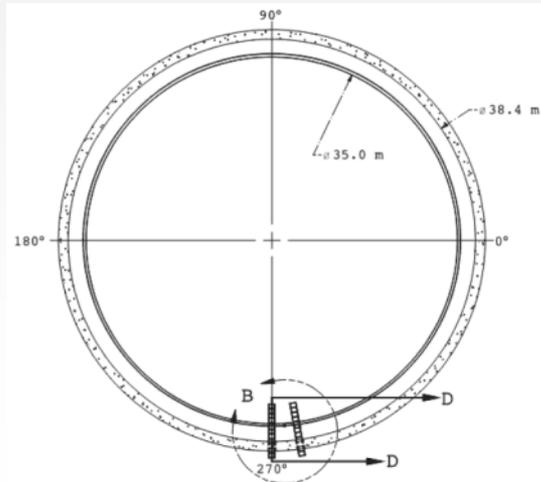
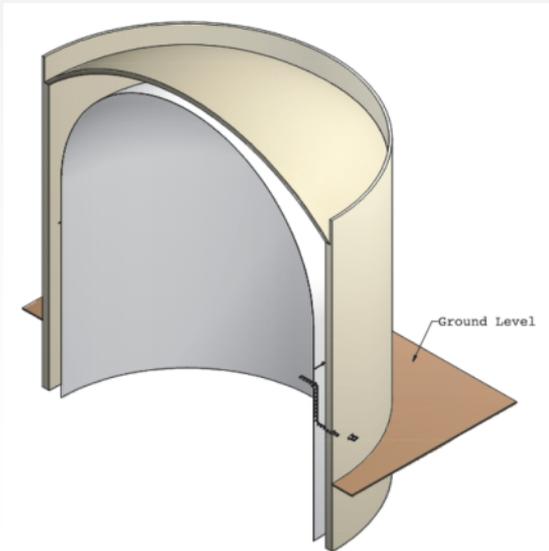
## F. Lube Oil Fire in a Turbine Building



## G. Transient Fire in a Multi-Compartment Corridor



## H. Cable Tray Fire in the Annulus



6



# Example: Fire in the Main Control Room

A.1 Modeling Objective

A.2 Description of the Fire Scenario

A.3 Selection and Evaluation of Fire Models

A.4 Estimation of Fire-Generated Conditions

A.5 Evaluation of Results

A.6 Conclusion

A.7 References

A.8 Attachments

## A.1 Modeling Objective

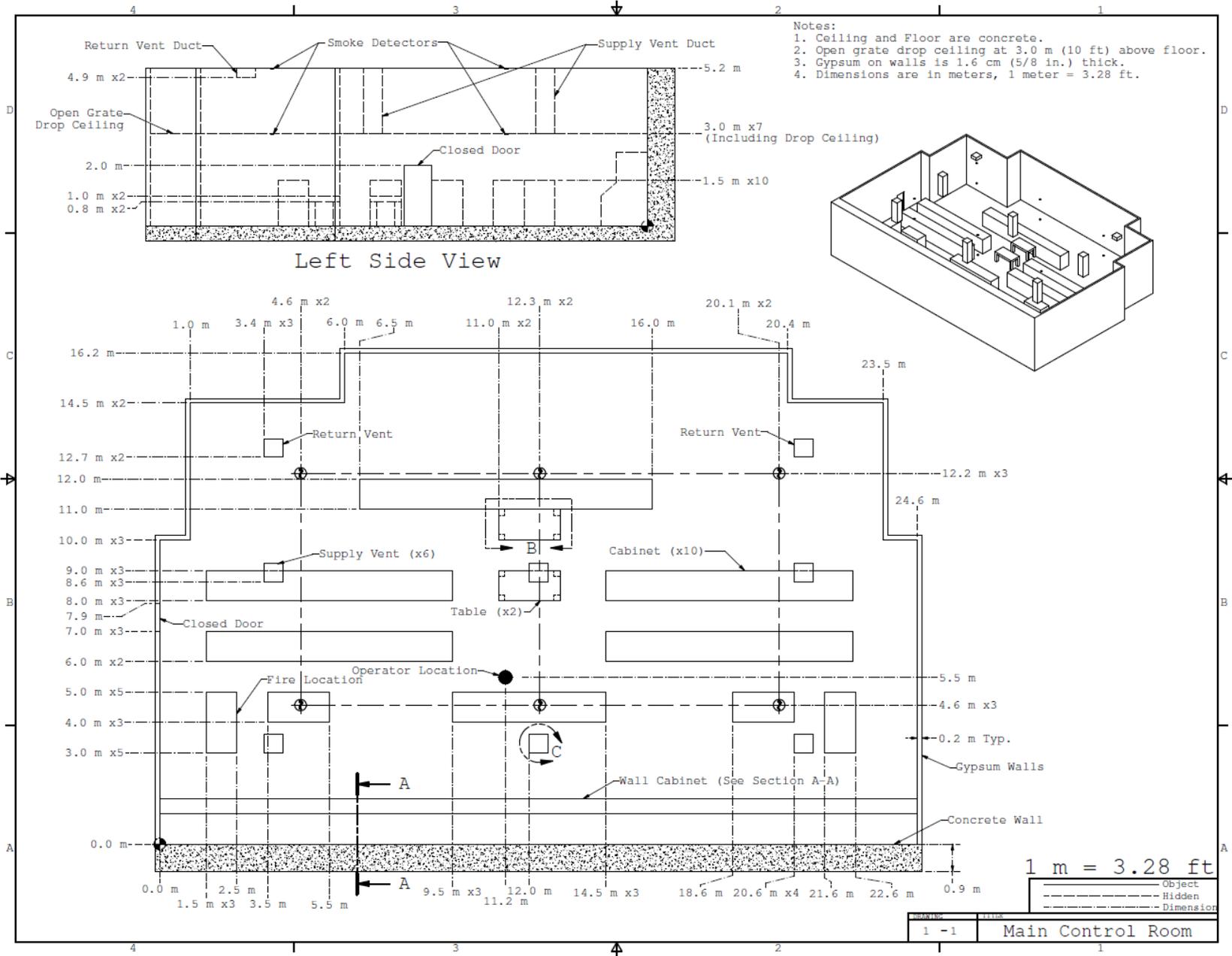
The purpose of the calculations described in this appendix is to determine the length of time that the main control room (MCR) remains habitable after the start of a fire within a low-voltage control cabinet. These calculations follow the guidance provided in NUREG/CR-6850 (EPRI 1011989), Volume 2, Chapter 11, “Detailed Fire Modeling (Task 11).” MCR fire scenarios are treated differently than fires within other compartments, mainly because of the necessity to consider and evaluate forced abandonment in addition to equipment damage.

**Habitability:** The MCR is manned 24 hours per day during normal plant operations. To assess habitability of the compartment, the operator position indicated in Figure A-1 is used. According to NUREG/CR-6850 (EPRI 1011989), Volume 2, Chapter 11, “Detailed Fire Modeling,” a space is considered uninhabitable if at least one of the following occurs:

1. The incident heat flux at 1.8 m (6 ft) exceeds  $1 \text{ kW/m}^2$ . A smoke layer temperature of approximately  $95 \text{ }^\circ\text{C}$  ( $200 \text{ }^\circ\text{F}$ ) generates this level of heat flux.
2. The smoke layer descends below 1.8 m (6 ft) from the floor, and the optical density of the smoke is greater<sup>9</sup> than  $3 \text{ m}^{-1}$ .

# A.2 Description of Fire Scenario

- Notes:
1. Ceiling and Floor are concrete.
  2. Open grate drop ceiling at 3.0 m (10 ft) above floor.
  3. Gypsum on walls is 1.6 cm (5/8 in.) thick.
  4. Dimensions are in meters, 1 meter = 3.28 ft.



## A.2 (cont.) Description of Fire Scenario

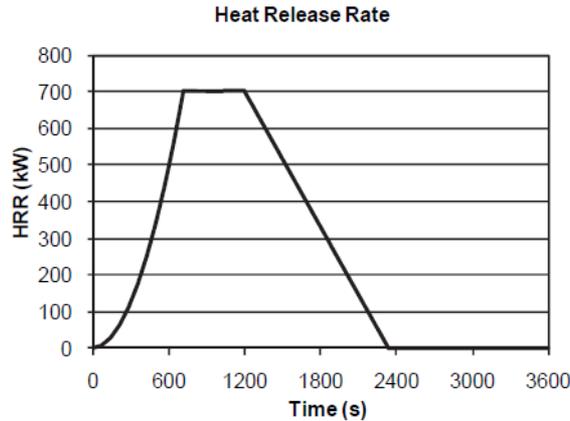
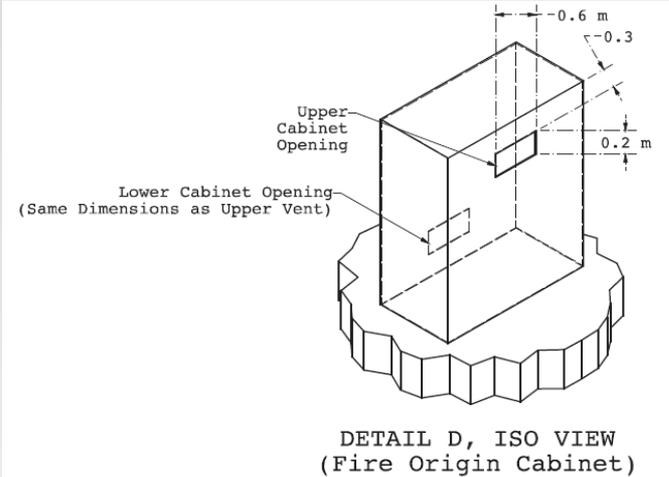


Figure A-5. Time history of the HRR used by all models in the MCR scenario.



DETAIL D, ISO VIEW  
(Fire Origin Cabinet)

Table A-1. Data for MCR fire based on XPE/neoprene electrical cable.

Parameter	Value	Source
Effective Fuel Formula	$C_3H_{4.5}Cl_{0.5}$	Combination of polyethylene and neoprene
Peak HRR	702 kW	NUREG/CR-6850 (EPRI 1011989), App. G
Time to reach peak HRR	720 s	NUREG/CR-6850 (EPRI 1011989), App. G
Heat of Combustion	10,300 kJ/kg	<i>SFPE Handbook</i> , 4th ed., Table 3-4.16
CO <sub>2</sub> Yield	0.63 kg/kg	<i>SFPE Handbook</i> , 4th ed., Table 3-4.16
Soot Yield	0.175 kg/kg	<i>SFPE Handbook</i> , 4th ed., Table 3-4.16
CO Yield	0.082 kg/kg	<i>SFPE Handbook</i> , 4th ed., Table 3-4.16
Radiative Fraction	0.53	<i>SFPE Handbook</i> , 4th ed., Table 3-4.16
Mass Extinction Coefficient	8700 m <sup>2</sup> /kg	Mulholland and Croarkin (2000)

## A.3 Selection and Evaluation of Fire Models

**Table A-2. Normalized parameter calculations for the MCR fire scenario. See Table 2-5 for further details.**

Quantity	Normalized Parameter Calculation	Validation Range	In Range?
Fire Froude Number	$\dot{Q}^* = \frac{\dot{Q}}{\rho_{\infty} c_p T_{\infty} D^{2.5} \sqrt{g}}$ $= \frac{702 \text{ kW}}{(1.2 \text{ kg/m}^3)(1.0 \text{ kJ/kg/K})(293 \text{ K})(0.4^{2.5} \text{ m}^{2.5})\sqrt{9.8 \text{ m/s}^2}} \cong 6.2$	0.4 – 2.4	No
Fire Height, $H_f + L_f$ , relative to the Ceiling Height, $H$	$\frac{H_f + L_f}{H} = \frac{2.1 \text{ m} + 2.7 \text{ m}}{5.2 \text{ m}} \cong 0.9$ $L_f = D \left( 3.7 \dot{Q}^{*2/5} - 1.02 \right) = 0.4 \text{ m} (3.7 \times 6.2^{0.4} - 1.02) \cong 2.7 \text{ m}$	0.2 – 1.0	Yes
Ceiling Jet Radial Distance, $r_{cj}$ , relative to the Ceiling Height, $H$	N/A – Ceiling jet targets are not included in simulation.	1.2 – 1.7	N/A
Equivalence Ratio, $\phi$ , of the Room, based on Forced Ventilation of Purge Mode	$\phi = \frac{\dot{Q}}{\Delta H_{O_2} \dot{m}_{O_2}} = \frac{702 \text{ kW}}{13,100 \text{ kJ/kg} \times 3.7 \text{ kg/s}} \cong 0.014$ $\dot{m}_{O_2} = Y_{O_2} \rho_{\infty} \dot{V} = 0.23 \times 1.2 \text{ kg/m}^3 \times 13.4 \text{ m}^3/\text{s} \cong 3.7 \text{ kg/s}$	0.04 – 0.6	No
Compartment Aspect Ratio	$\frac{L}{H} = \frac{24.6 \text{ m}}{5.2 \text{ m}} \cong 4.7$ $\frac{W}{H} = \frac{16.2 \text{ m}}{5.2 \text{ m}} \cong 3.1$	0.6 – 5.7	Yes
Target Distance, $r$ , relative to the Fire Diameter, $D$	$\frac{r}{D} = \frac{8.8 \text{ m}}{0.4 \text{ m}} \cong 22$	2.2 – 5.7	No



Require Justification

Notes:

- (1) The effective diameter of the base of the fire,  $D$ , is calculated using  $D = \sqrt{4A/\pi}$ , where  $A$  is the area of the cabinet vent.
- (2) The Fire Height,  $H_f + L_f$ , is the sum of the height of the fire off the floor plus the fire's flame length.

## A.3 (cont.) Selection and Evaluation of Fire Models

### Justifying use of the model when the application falls outside of the validation range

For the scenario with no ventilation, the classic definition of the Equivalence Ratio does not apply because there is no supply of oxygen in the room. However, it can be shown that there is sufficient oxygen in the room to sustain the specified fire. The total mass of oxygen in the room is the product of the density of air,  $\rho$ , the volume of the room,  $V$ , and the mass fraction of oxygen in the air,  $Y_{O_2}$ :

$$m_{O_2,tot} = \rho V Y_{O_2} = 1.2 \text{ kg/m}^3 \times 1945 \text{ m}^3 \times 0.23 \cong 537 \text{ kg} \quad (\text{A-1})$$

The mass of oxygen required to sustain the fire is equal to the total energy produced by the fire divided by the energy released per unit mass oxygen consumed:

$$m_{O_2,req} = \frac{Q}{\Delta H_{O_2}} \cong \frac{702 \text{ kW} \times 60 \text{ s/min} \times \left(\frac{12}{3} + 8 + \frac{19}{2}\right) \text{ min}}{13,100 \text{ kJ/kg}} \cong 69 \text{ kg} \quad (\text{A-2})$$

These calculations show that the quantity of oxygen in the room would be able to sustain the specified cabinet fire.

## A.4 Estimation of Fire-Generated Conditions

Start with empirical models first

(Foote, Pagni, Alvarez Correlation for Closed, Ventilated Compartment)

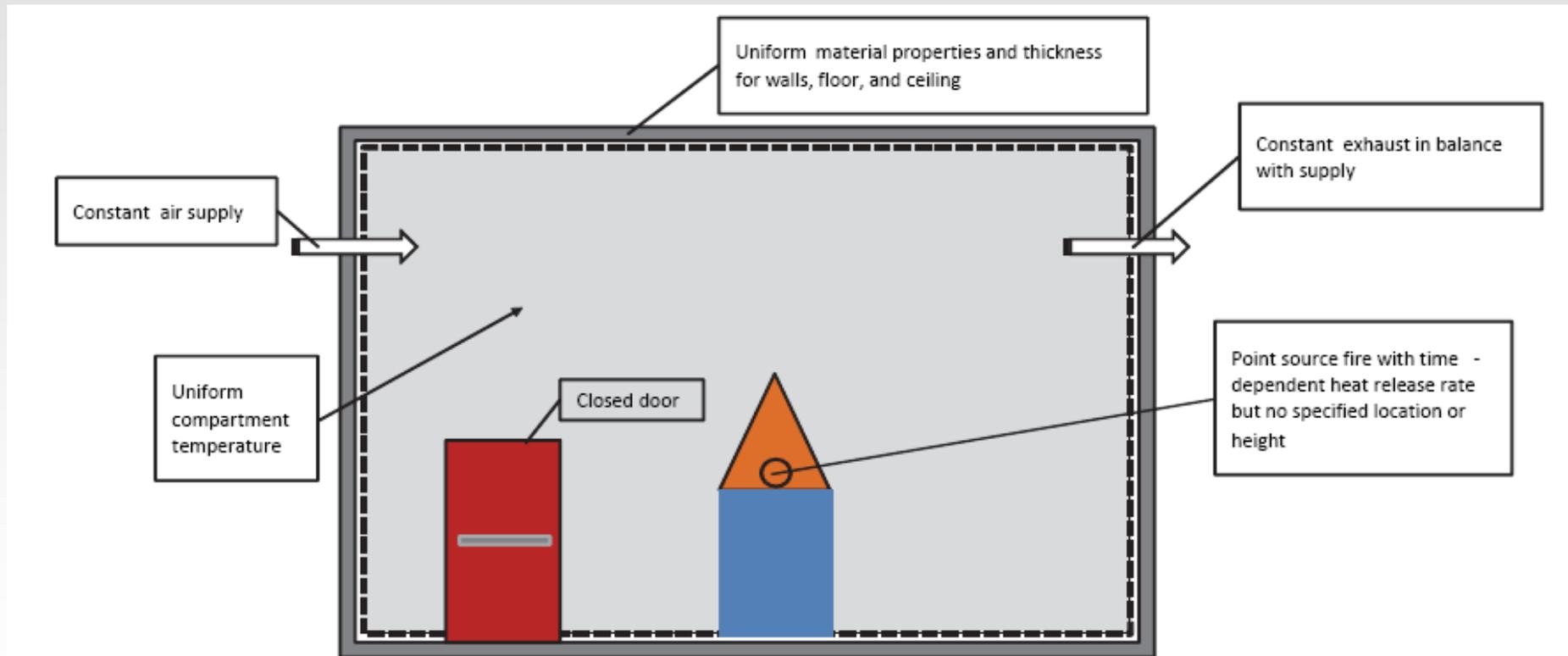
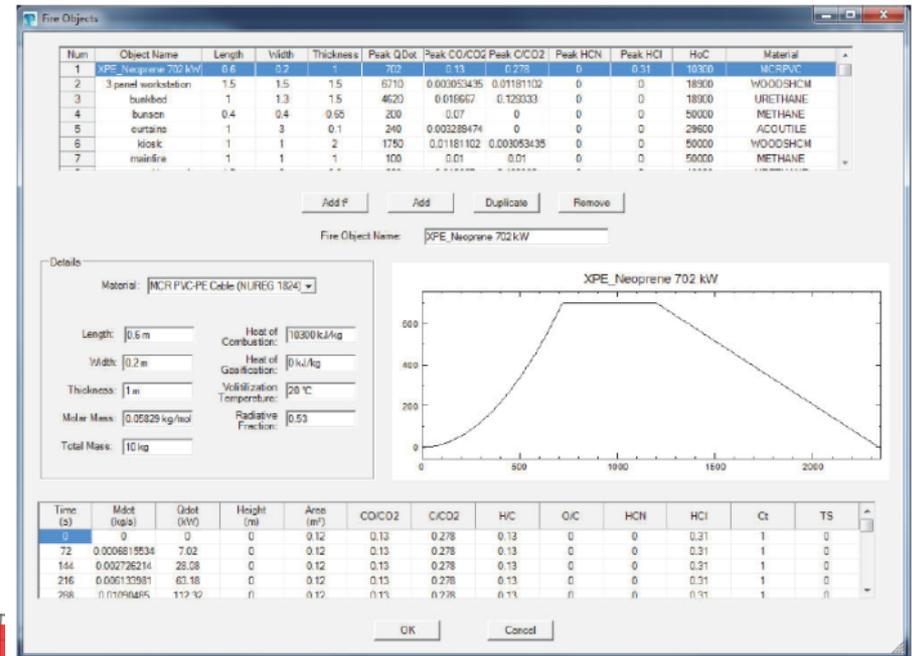
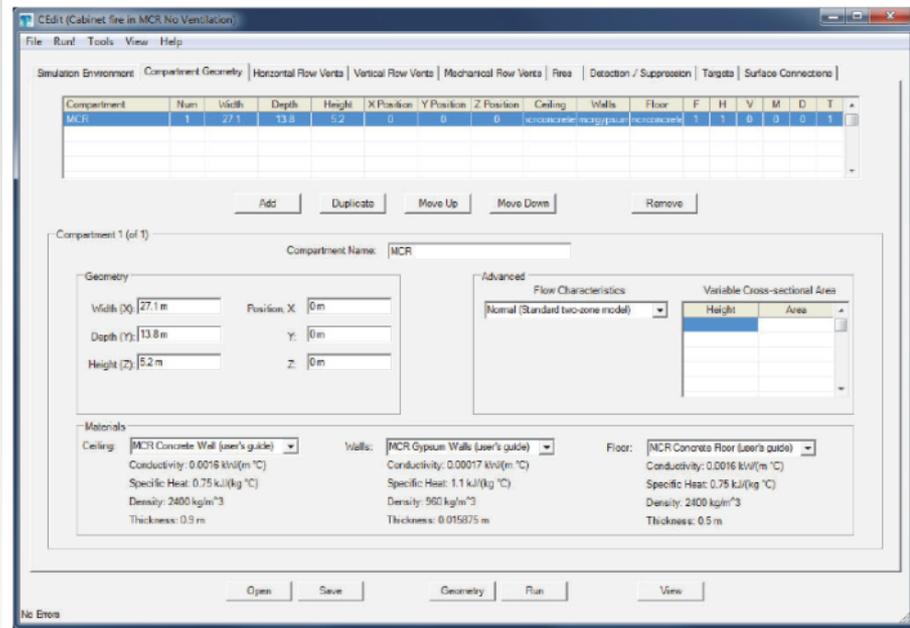


Figure A-6. Schematic diagram of the FPA calculation for the MCR smoke purge scenario.

# A.4 (cont.) Estimation of Fire-Generated Conditions

Move to next level of complexity (zone models) if empirical correlations cannot address all of the failure criteria.



Note: Values for "Total Mass," "Heat of Gasification," and "Volatilization Temperature" are set at default values.

Frame: 120  
Time: 1200.0

Figure A-10. Snapshot of the CFAST simulation of the MCR fire with mechanical ventilation.

## A.4 (cont.) Estimation of Fire-Generated Conditions

Move to next level of complexity (CFD model) if there is a need for a “second opinion”.

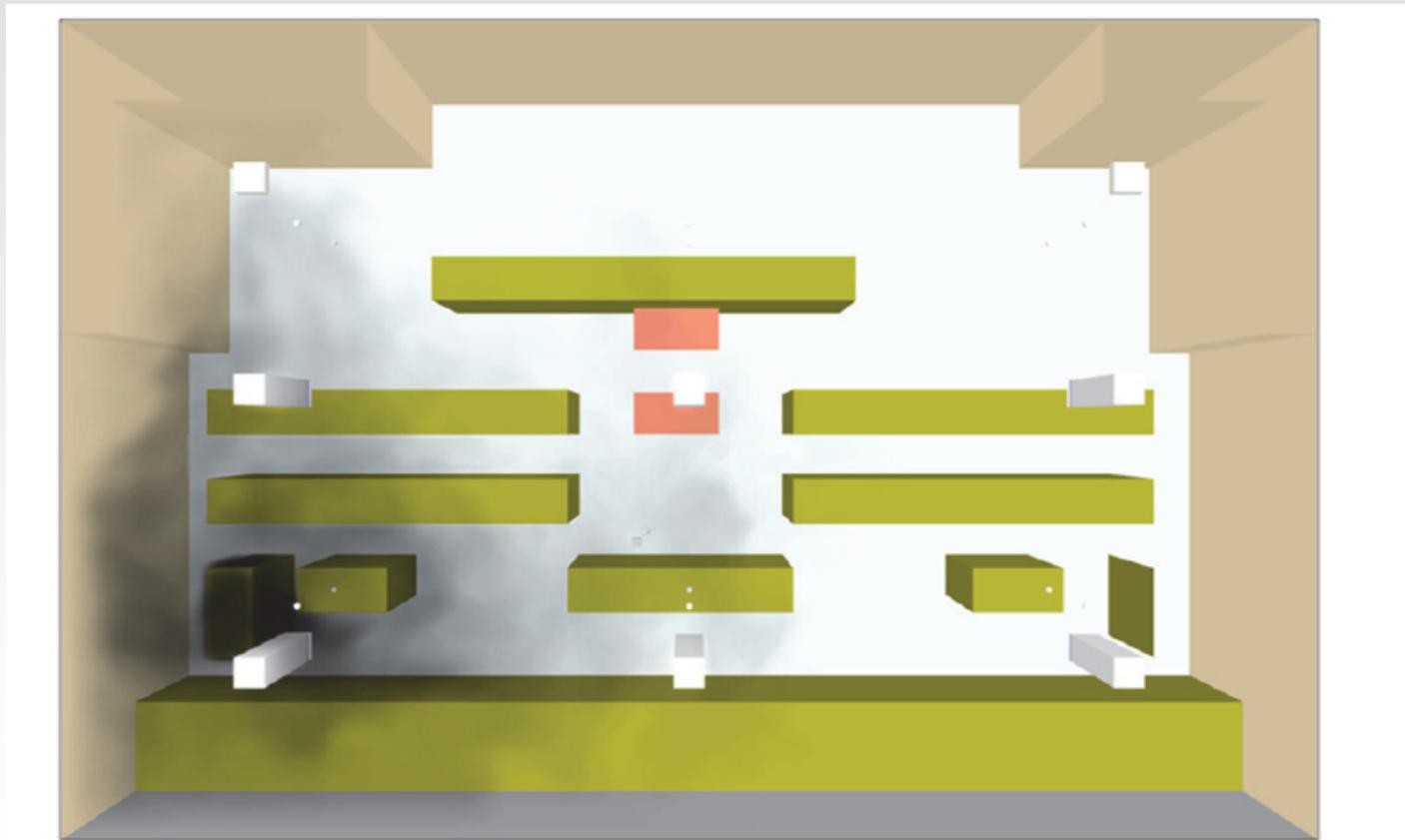


Figure A-11. FDS/Smokeview rendering of the MCR, as viewed from above.

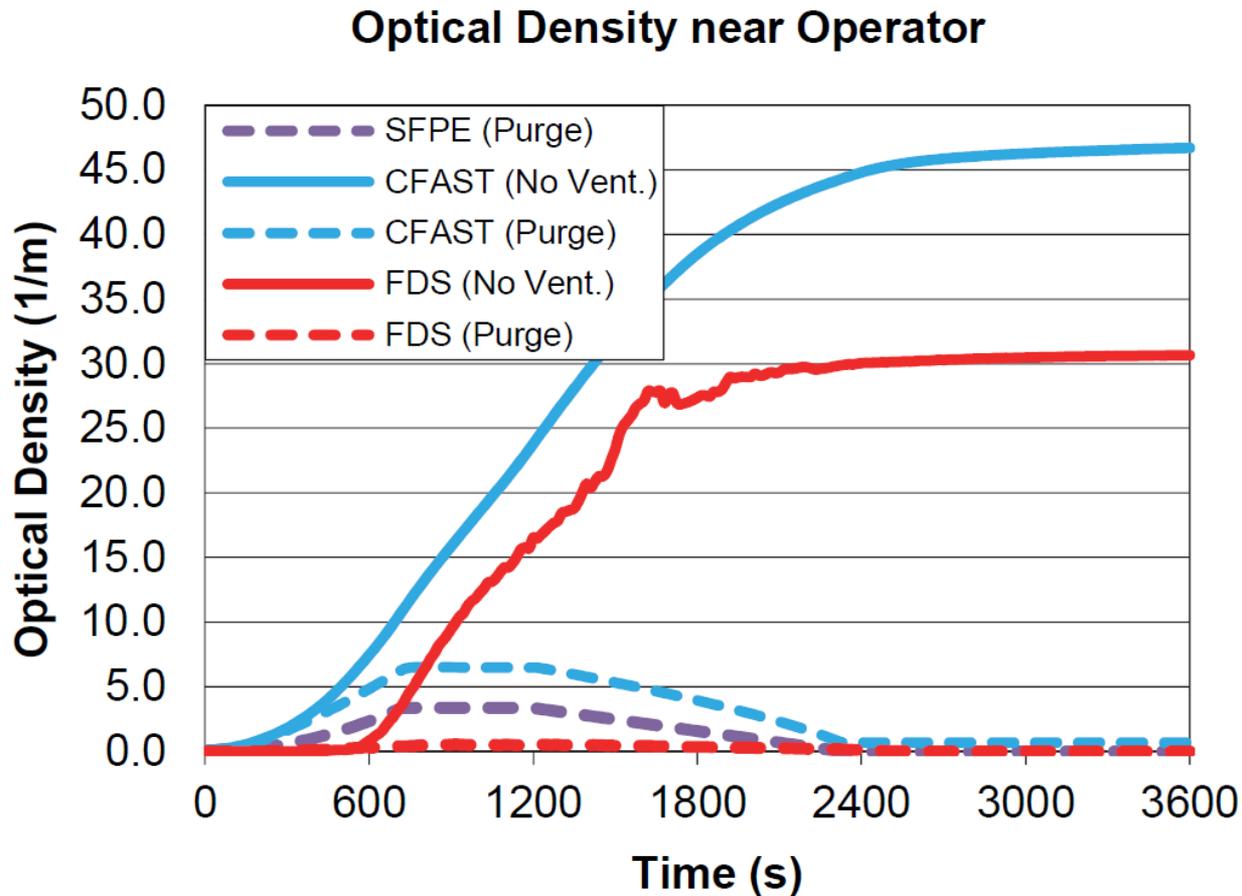
## A.5 Evaluation of Results

Table A-4. Summary of the model predictions of the MCR scenario.

Model	Bias Factor, $\delta$	Standard Deviation, $\tilde{\sigma}_M$	Ventilation	Predicted Value	Critical Value	Probability of Exceeding
<b>Temperature (°C), Initial Value = 20 °C</b>						
FIVE (FPA)	1.56	0.32	Purge	70	95	0.000
CFAST	1.06	0.12		60	95	0.000
FDS	1.03	0.07		48	95	0.000
CFAST	1.06	0.12	No Vent.	82	95	0.009
FDS	1.03	0.07		70	95	0.000
<b>Heat Flux (kW/m<sup>2</sup>)</b>						
FIVE	1.42	0.55	Purge	0.4	1	0.000
CFAST	0.81	0.47		0.1	1	0.000
FDS	0.85	0.22		0.2	1	0.000
CFAST	0.81	0.47	No Vent.	0.6	1	0.228
FDS	0.85	0.22		0.4	1	0.000
<b>Optical Density (m<sup>-1</sup>)</b>						
CFAST	2.65	0.63	Purge	6.5	3	0.362
FDS	2.7	0.55		0.5	3	0.000
CFAST	2.65	0.63	No Vent.	47	3	0.906
FDS	2.7	0.55		31	3	0.909

## A.5 (cont.) Evaluation of Results

Focus in on the phenomenon that is most likely to be a cause for concern.



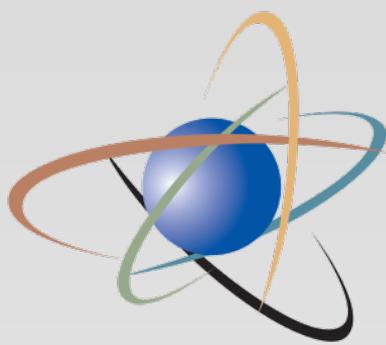
**Figure A-14. Optical density predictions for the MCR scenario.**

## A.6 Conclusion

A fire modeling analysis has been performed to assess the habitability of the MCR in the event of a fire within an isolated electrical cabinet. The fire is not expected to spread to other cabinets. Of the three MCR abandonment criteria, it is most likely that the operators would be forced to abandon the MCR because the optical density would surpass  $3 \text{ m}^{-1}$  approximately 12 minutes after the fire ignites if the smoke purge system is not activated before this time, according to the FDS analysis. A simple analytical method and the zone model CFAST indicate that the optical density would exceed the critical value with the smoke purge system on and with the ventilation system turned off. However, these analyses are based on several important assumptions. For the smoke purge case, the analytical method assumes that the smoke fills the entire compartment uniformly, even though the FDS analysis shows that the supply vents maintain visibility in the vicinity of the operator location. CFAST reports the optical density of the upper layer, but does not predict that the upper layer would descend to the level of the operator in either the purge or no ventilation scenario based on the specified assumptions.

## A.7 References

1. NUREG-1805, *Fire Dynamics Tools*, 2004.
2. NUREG/CR-6850 (EPRI 1011989), *Fire PRA Methodology for Nuclear Power Facilities*, 2005.
3. NUREG-1824 (EPRI 1011999), *Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications*, 2007.
4. *SFPE Handbook of Fire Protection Engineering*, 4<sup>th</sup> edition, 2008.
5. NIST SP 1018-5, *Fire Dynamics Simulator (Version 5), Technical Reference Guide, Vol. 3, Experimental Validation*.
6. NIST SP 1030. *CFAST: An Engineering Tool for Estimating Fire Growth and Smoke Transport, Version 5 - Technical Reference Guide*, National Institute of Standards and Technology, Gaithersburg, Maryland, 2004.
7. G.W. Mulholland and C. Croarkin. "Specific Extinction Coefficient of Flame Generated Smoke." *Fire and Materials*, 24:227–230, 2000.



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## Conclusion

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**Office of Nuclear  
Regulatory Research**



*Fire Research  
Branch*



# Conclusion

- Team believes NUREG-1934/EPRI 1023259 ready for publication:
  - Fulfills the need to support Quality Fire Model Implementation and Review
  - Fulfills the need to support Education and Training
  - Request a ACRS Letter
- Future Fire Modeling Projects
  - Compile catalogue Fire Model Material Properties
  - Expand Fire Model V&V NUREG-1824