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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON REACTOR SAFEGUARDS

(ACRS)

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RELIABILITY AND PRA SUBCOMMITTEE

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WEDNESDAY

MARCH 21, 2012

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ROCKVILLE, MARYLAND

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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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

MR. SALLEY: Great.

CHAIR STETKAR: We have no lives.

(Laughter.)

MR. SALLEY: Wonderful.

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

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

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

We got a NUREG brochure, BR-0361, that we put out a few years ago, and this is part of our knowledge management to capture it. And if you look at this one, you will find in the video section there is an interview that Jack did at the TTC with Mark Miller before he retired. We are in the process of changing this into a new series called NUREG/KMs, for knowledge management. We are going to be adding Jack's seminar that he did two years ago to this and capture that.

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

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

(Laughter.)

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

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

Okay. With that, I just wanted to do that and get on with today. To change gears here, today is an important day for us. We are going to talk about a project that we have worked with EPRI for a while. Rick Wachowiak is, of course, the EPRI side, my counterpart in EPRI. So, we are going to open this up and talk to you and get the slides.

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

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

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

I thought it would be good to start out, just to give you a very, very abbreviated, short history of the impact of fire modeling in the U.S. nuclear power plants. It all goes back to the very beginning, if you want to get into the very elementary fire modeling. Back in the sixties and seventies, when a lot of the plants were still on the drawing board, one of the concepts we were using back then was compartmentation. We knew compartmentation was important for a lot of reasons, fire protection being one of them.

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

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

It is also interesting, in 1980, if you read the Statements of Consideration for Appendix R, that the rule, as it came out -- and you are very well aware -- it was very prescriptive. It called out for one-hour fire barriers with automatic suppression and detection, and it called out for three-hour rated fire barriers. Even back when that was being promulgated and going through the public stakeholder interventions, you will read some of the comments, and the industry wanted to go with a design basis fire way back in the late 1970s and early eighties. Of course, to get to design basis fire, you need some form of model to give you that fire.

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

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

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

As a matter of fact, this even spawned

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

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

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

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

In 2004, we also published NUREG-1805 where we are starting to work with our inspectors to have them think in terms of fire dynamics, and not just a rated three-hour barrier looking at a test, but to look at the hazard and what kind of fire can you get from that hazard. And we start to introduce fire dynamics to them in their training methods.

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

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

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

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

MR. WACHOWIAK: Okay. Thanks.

Good morning, for everybody.

CHAIR STETKAR: Afternoon.

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

(Laughter.)

I'm not from around here.

(Laughter.)

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

(Laughter.)

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

So, that is how we did this project, under that Memorandum. We put together a team that included NRC fire modeling experts, industry experts, including the vendors and the consultants that are actually out there performing the fire modeling at the plants. We involved NIST in this. They were involved with a lot of the testing, fire testing, that we have done that manifests itself in these examples. And we also went out to universities and looked for their input from the research that they have been doing.

Go ahead.

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

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

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

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

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

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

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

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

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

Our second round through with the fire

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

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

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

MEMBER BLEY: It is? Okay.

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

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

MEMBER BLEY: Okay.

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

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

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

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

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

MEMBER BLEY: And that is the sixth module?

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

MEMBER BLEY: The fifth module.

MR. WACHOWIAK: The fifth module.

The Monday day for the entire training is a fundamentals sort of thing, and there is no fundamentals of advanced fire modeling. That is the fire modeling course itself.

(Laughter.)

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

CHAIR STETKAR: Are you still getting pretty good attendance?

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

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

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

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

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

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

MR. WACHOWIAK: Based on the training course?

MEMBER SCHULTZ: That's right.

MR. WACHOWIAK: The majority of the changes that were made there were to discuss how you use the empirical correlations in concert with the computer models. I think the document itself, the examples were very focused on the use of the computer tools.

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

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

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

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

MR. SALLEY: That was also between the first and second draft. I guess when we initially started this, I will take responsibility or blame for this, as being way too overzealous where I wanted this to be the end-all, be-all Fire Modeling Applications Guide. I mean, you always shoot for the moon, right?

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

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

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

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

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

CHAIR STETKAR: Thank you.

MR. WACHOWIAK: Thank you. Good point.

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

CHAIR STETKAR: Yes.

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

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

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

Are there any other questions for us?

(No response.)

Okay.

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

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

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

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

(Laughter.)

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

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

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

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

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

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

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

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

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

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

CHAIR STETKAR: No. I was going to just

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

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

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

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

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

MEMBER ABDEL-KHALIK: Right. Okay.

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

One of the reasons I took the approach in preparing this presentation to try to find a balance between slides that provided some level of information, but, more importantly, stimulated questions, because I didn't want to, basically, sit up here and recite the stuff that was already in the report.

MEMBER ABDEL-KHALIK: Okay.

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

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

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

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

MEMBER ABDEL-KHALIK: Right.

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

MEMBER ABDEL-KHALIK: I fully understand

that.

MR. McGRATTAN: Okay, okay.

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

MR. McGRATTAN: Yes.

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

MR. McGRATTAN: Yes.

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

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

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

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

MR. McGRATTAN: Yes.

MEMBER ABDEL-KHALIK: And have you done it for coal?

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

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

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

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

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

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

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

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

MR. McGRATTAN: Right.

MEMBER ABDEL-KHALIK: Okay.

MR. McGRATTAN: Yes. So, keep in mind that, when we discuss fires in nuclear power plants, we are typically burning cable jackets, insulation, you name it, for which the heats of combustion are not very well-known. In fire, we take that 13,000 number when we don't have more specific data. So, that would be fairly robust in describing a wide variety of fuels.

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

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

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

MR. McGRATTAN: Yes, yes.

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

MR. PEACOCK: I am Rick --

CHAIR STETKAR: You're on.

MR. PEACOCK: I am Rick Peacock from NIST.

Most of that comes from a peer review journal article. It is largely a wide range of hydrocarbon fuels. That journal article certainly didn't get the hydrogen --

MEMBER ABDEL-KHALIK: Right.

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

So, I think the answer is everybody is right.

(Laughter.)

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

MR. PEACOCK: Right.

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

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

MEMBER ABDEL-KHALIK: Okay.

CHAIR STETKAR: Dave, go on.

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

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

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

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

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

When NRC adopted 805 in the regulations, it was then necessary to try to figure out what that verification and validation really meant. It was only the words and the requirement were in 805; it really didn't give you any guidance as to how to go about doing that.

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

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

And specifically, during our presentations to the ACRS at the time, we promised them that we would do this Users' Guide. When they sent the letter supporting publication of the Users' Guide, they had a couple of requirements, which I think we have done a pretty good at this stage of addressing. And that is estimating ranges or parameters over which the fire models are applicable and, also, taking that big step, as I see it, towards providing quantitative estimates of the uncertainty.

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

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

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

That range, it is based on the V&V that we have, that it is certainly a limited set of experiments. "Limited" is a relative term. And future work, as you will hear, involves expanding that to realize those ranges.

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

MEMBER BLEY: They tell later on, actually.

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

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

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

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

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

MR. McGRATTAN: Right.

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

MR. JOGLAR: Our V&V study, it doesn't validate a model; it validates capabilities of the model. And some of the correlations that are included in those models are also evaluated separately, independently.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

But, right now, we have been getting questions as far as, you know, the big one, "What do I do if it is outside the validation range?" And also, "Well, you validated FDS Version 3. I'm using Version 5. When is NRC going to approve the latest version?"

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

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

MR. JOGLAR: From the application side -- and this is my own experience -- now when you use these models, you need in your documentation to argue why it is good. To the extent that you are within the bounds of this V&V, that gives you a good argument for that. To the extent that you fall outside, you have to come up with those justifications, which is a step in the right direction in terms of -- so, yes, from the applications, yes, it involves now a justification of why this calcs are good.

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

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

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

Now, given the fact that most of the real fire scenarios that the people in the trenches are actually struggling with today are outside of the validation range of the models that they are being told to use, does NRR formally accept the methods in NUREG-1934 as justification to support the analyses that people are doing today? And if so, where is that documented, so that the people doing the analyses know what sort of guidance to use?

I saw you Alex. I knew you were there.

(Laughter.)

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

CHAIR STETKAR: I'm sure you do.

Identify yourself.

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

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

And we will ask that licensee, if we believe that licensee is not providing us with enough basis or documentation as to why they believe the application of that model outside of that validation range is acceptable, we will go back to that licensee, and we have been.

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

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

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

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

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

So, you know, in terms of validity, you

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

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

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

It would seem that it should get a little more attention, both in this document, but without research kind of running off in one direction without close interaction with NRR, who is then going to come back and bring people and say, "Well, we have no justification."

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

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

MEMBER ABDEL-KHALIK: Well, let me just point to a specific case where this may be a problem, the case of underventilated compartment fires, and none of the V&V calculations really cover that range. And the argument is made in the text that, if they were to assume it to be well-ventilated, that that would be a conservative assumption, but that may not be reality.

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

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

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

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

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

MR. JOGLAR: Which scenario specifically?

MEMBER ABDEL-KHALIK: The assumed

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

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

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

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

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

MR. JOGLAR: More fire --

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

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

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

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

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

MR. McGRATTAN: I don't think that is what it says at all. I think we are putting the onus on the user of the model to justify why they are using it in the way they are. I don't think it is carte blanche to do whatever you want.

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

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

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

MR. McGRATTAN: And I will add something that is funny. One of the reasons why it took so long to develop this guide, and why it went through public comment twice, is that we, ourselves, when we became the users and worked these eight examples, the reviewers a number of times said, "Well, wait a second. How can you" -- and we said, yes, we can. We didn't follow our own advice a number of times, and we found, when we had to justify why we were using a particular model outside of its range, sometimes we had to throw those analyses out because we couldn't ourselves do it.

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

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

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

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

I know we are a little bit late, but I wanted to follow up just with a question for myself, and it would be more an industry question. When I first got involved with commercial plants, I was kind of surprised they weren't rigged like surface ships in the Navy that I had seen. There, if you had a fire, you kill the inlet fans and you put the outlet fans on the high speed. Then, I found out a lot of plants don't have that capability. They would have to rewire that.

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

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

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

MEMBER BLEY: Just because of the openness in there.

MR. McGRATTAN: Yes.

MEMBER BLEY: Yes. That kind of makes

sense.

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

MEMBER BLEY: Yes.

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

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

MEMBER BLEY: Right.

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

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

MEMBER BLEY: I take it that hasn't come

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

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

MEMBER BLEY: Okay.

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

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

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

CHAIR STETKAR: Well, but people

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

MR. McGRATTAN: Right.

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

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

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

MR. McGRATTAN: Right. Correct.

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

MEMBER BLEY: Without justification, further justification.

CHAIR STETKAR: Without further justification.

MR. JOGLAR: As a fire-modeling analyst, I know the NUREGs that were written describing THIEF and FLASH-CAT, and I referenced those as having the validation there. So, I guess what --

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

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

Hi, Alex.

(Laughter.)

MR. KLEIN: Hi, John.

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

CHAIR STETKAR: Okay. I'm sorry.

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

With respect to a licensee's use of, say, FLASH-CAT or THIEF, or anything -- call it an XYZ fire model -- if a licensee wants to propose use of a fire model to the regulator, NRR, and, say, transition to NFPA 805, we look for that licensee to be able to demonstrate to us that they have done proper verification and validation of that model, and that they have used that within the applicable range of that model.

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

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

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

If I want to use one of those models, can I simply now refer to this set of NUREGs in the way that I can refer to 1824, as long as I justify that my application is within the V&V range of the five models in 1824? Or, if I want to use THIEF and FLASH-CAT, do I need to build my own case 47 times because individual applicants will have 47 different problems for those models? That is the concern.

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

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

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

MR. KLEIN: Okay.

CHAIR STETKAR: Thanks.

MR. SALLEY: If I could just follow up

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

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

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

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

(Laughter.)

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

(Laughter.)

But, for like vertical trays, you will be seeing that we will be working in 2013 and 2014. So, this process never ends. It keeps --

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

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

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

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

So, if you pull Volume 3 of CAROLFIRE, you will see how we did the one-dimensional heat transfer that Kevin did to create THIEF, and then how it was validated with other experiments in that series independently. So, we work it together. I mean, we understand the process.

CHAIR STETKAR: Okay. Thanks, Mark.

Dave?

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(Laughter.)

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

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

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

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

CHAIR STETKAR: Okay. Good. Thanks.

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

CHAIR STETKAR: A couple of minor things on Chapter 2, actually several, but they are kind of minor. But it is important, when you write a document, to kind of understand how people might interpret or misinterpret the words.

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

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

I don't think that is the intent of NFPA

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

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

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

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

I know in preparing for this meeting, I was re-reading some of those sections and realized that in a lot of cases I think some of the language was pulled in directly out of the document, out of 805, and probably was not really written in a plain, understandable fashion to say what it really was intended to mean.

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

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

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

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

MR. JOGLAR: Right, right.

CHAIR STETKAR: -- for example, some recommendation that says, you know, use the 98th percentile or the 2nd percentile, depending on which extreme gives you the most conservative results of the underlying uncertainty distributions, I think this document ought to at least present that sort of general approach, rather than just saying, "Use the best estimate."

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

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

MR. JOGLAR: Yes, the ventilation, you

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

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

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

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

(Laughter.)

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

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

(Laughter.)

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

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

At a high level, I think the only comment I want to make here is that we will have an opportunity, I think, to discuss some of these questions that you are bringing up here when we come to your Subcommittee in the July timeframe.

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

CHAIR STETKAR: No, no.

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

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

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

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

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

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

CHAIR STETKAR: Okay. Good. Thanks.

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

MR. JOGLAR: In my own experience doing that for outside of PRA, we took an approach, but with the understanding that perhaps when it gets to the NRR we will get questions and discussions because it is not clear.

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

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

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

Oh, this is just a question. It is really good. One thing I really liked, there is a Section 2.2.3 that makes extensive reference to NUREG/CR-6738, which is "Risk Methods/Insights Gained from Fire Incidents". It says, look, when you start characterizing your fires and building your analysis and your models, it is really good to go back and look at what has happened in the industry.

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

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

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

My question is, does RES currently have a plan to update that NUREG? And if you don't, maybe you ought to think about it, because we have had a number of kind of interesting fires that have occurred over the last 20 years. Documentation is a lot better. Sensitivities to documenting what has gone on, the staff's and the industry's sensitivity to understanding fires has been enhanced quite a bit.

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

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

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

We also have a program for international.

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

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

MR. JOGLAR: Some of the interesting fires after that are in NUREGs, like the high-energy arcing faults. We have captured that guidance in 6850, for example. So, it doesn't necessarily mean that we have missed those interesting fires in subsequent documents, but they are not compiled in a single document looking for risk insights that that document was doing.

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

It is not actually a frequency distribution. It is a conditional probability distribution. It is just a minor point, but there is going to be a theme here in my comments through the rest of the afternoon that, when you are talking about uncertainties, when you are talking about probability distributions, you ought to use the correct terminology. Otherwise, all it does is cause more confusion.

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

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

MEMBER ABDEL-KHALIK: Ceiling jet ratio.

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

MEMBER ABDEL-KHALIK: Page 226.

CHAIR STETKAR: Thank you.

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

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

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

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

CHAIR STETKAR: My job is done here.

(Laughter.)

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

CHAIR STETKAR: Thanks.

MR. McGRATTAN: Yes.

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

(Laughter.)

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

(Laughter.)

CHAIR STETKAR: I don't do public comments.

That is all I had on Chapter 2.

Did any other Members have any comments or questions on Chapter 2?

(No response.)

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

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

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

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

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

MR. SALLEY: Yes, before Francisco starts.

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

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

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

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

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

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

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

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

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

And we did that because, further on, we have very detailed examples where all the complexities of fire models are treated. We wanted these to serve as a qualitative overview of the process. We think it helps those most common applications in the industry now, which is NFPA 805 and the fire PRAs.

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

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

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

You talk about why you probably shouldn't model the incipient stage of fire growth. The statement that is made, which is true, it says, "Because of the uncertainty in the intensity of the fire during this stage and the exact time that a fire will transition to a significant fire, the incipient stage is often not considered in the analysis."

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

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

But if you are tossing out some number of very small or insignificant fires, it is not at all clear how well you are justified now developing a model that says, well, I've got ignition, so I can now model the incipient stage of the fire. And you may want to acknowledge that.

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

MR. WACHOWIAK: Yes, this is Rick Wachowiak.

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

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

CHAIR STETKAR: That were through that, essentially.

MR. WACHOWIAK: Right, right.

CHAIR STETKAR: Or partially through that phase.

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

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

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

MR. WACHOWIAK: Right.

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

MR. WACHOWIAK: Right.

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

MR. JOGLAR: In our fire PRA trainings, that is the guidance that we provide from a purely modeling perspective. We don't know how long it is, and we are not going to get anything new out of the model for modeling in an incipient thing. We are not going to change room conditions if we add that.

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

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

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

MEMBER SCHULTZ: That database is skewed.

So, caution needs to be provided.

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

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

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

MR. WACHOWIAK: Yes.

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

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

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

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

MR. WACHOWIAK: In 6850 --

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

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

MEMBER ABDEL-KHALIK: Okay.

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

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

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

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

Scenario No. 4, what we want to highlight here is not only targets that are away, but it is complex geometries. Most of our rooms will have complex geometries, and we have provided guidance on how to deal with them in the application of different models.

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

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

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

There are three requirements to address fire damage to structural steel elements. And we have added an example in our guide just in case you have to use a fire model to address those. Sometimes you just fail the turbine building and that's it. But just in case you need to analyze it, we have provided an example for such bigger fires.

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

MR. JOGLAR: Yes.

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

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

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

MR. JOGLAR: Well, we are trying in Scenario 5, usually, the reason why we solve it is to determine when we have to leave the control room. Maybe this doesn't answer your question, but I see it as, if you have to leave the control room, it doesn't matter if you can stay in one part of the control room and not in another. You have to leave.

And for that --

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

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

MEMBER ABDEL-KHALIK: Yes.

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

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

MEMBER ABDEL-KHALIK: It is inherent, right?

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

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

MR. McGRATTAN: Right.

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

MR. McGRATTAN: Right.

MEMBER ABDEL-KHALIK: -- more details.

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

MEMBER ABDEL-KHALIK: Absolutely.

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

MEMBER ABDEL-KHALIK: Right, right. But, in this particular case, where this is as far as control room habitability, and when the people have to leave the control room, it seems to me that saying that you can do based on a homogenized model is inherently non-conservative.

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

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

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

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

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

MEMBER ABDEL-KHALIK: But if I know that the model is going to be non-conservative in the first place -- anyway, I think it is --

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

MEMBER ABDEL-KHALIK: You need to abandon?

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

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

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

MR. JOGLAR: I understand.

MEMBER ABDEL-KHALIK: Right? And the same thing about fire Scenario 7. Presumably, you are doing this to get temperature histories for the structures, so that you can do a detailed structural analysis to find out whether the structures would fail or not. But if you are using a zone model, would you be able to get detailed spatial variations of temperature, not just the temporal variations of temperatures, that would allow you to do a detailed structural analysis?

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

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

MEMBER ABDEL-KHALIK: Right.

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

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

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

MR. McGRATTAN: Okay.

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

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

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

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

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

MEMBER ABDEL-KHALIK: I think the same

applies for 5 as well.

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

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

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

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

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

MR. McGRATTAN: Right.

MEMBER ABDEL-KHALIK: -- down to that.

MR. McGRATTAN: I'm sorry.

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

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

MR. McGRATTAN: Yes.

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

MR. McGRATTAN: Right.

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

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

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

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

CHAIR STETKAR: By the way, in practice, like I said, I am not a fire modeler, but for main control room abandonment, if I am doing a real fire analysis, there are a lot of other things that I need to consider, like, for example, if the fire is burning instrumentation and controls, so I don't know what the heck is going on in the plant, all of this stuff about smoke layer and temperatures is sort of irrelevant.

MR. JOGLAR: Correct.

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

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

CHAIR STETKAR: Okay.

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

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

MR. JOGLAR: Sure.

CHAIR STETKAR: It is just sensitivity that somebody who is doing a real analysis -- just because it says you don't have to abandon the control room for 37.62 minutes for this thing doesn't mean that the people are actually going to stay there that long.

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

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

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

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

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

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

And the guidance we are providing is in terms of sensitivity analysis or referencing other validation studies. Of course, this is followed up, like what Mark was saying, by more research in terms of V&V. So that we can, hopefully, extend those ranges.

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

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

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

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

MR. JOGLAR: Yes.

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

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

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

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

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

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

MR. JOGLAR: No, but it is probably a good idea to check that, when we say makes it much more severe, there is enough there to make it clear what "more severe" means.

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

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

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

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

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

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

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

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

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

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

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

MEMBER BLEY: Well, it is always like

that; it is no problem -- yet.

MR. JOGLAR: Yes. I understand.

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

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

With that, we can go to Chapter 4.

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

(No response.)

Now you can switch gears.

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

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

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

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

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

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

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

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

MEMBER BLEY: Kevin?

MR. McGRATTAN: Yes?

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

MR. McGRATTAN: Right.

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

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

Model uncertainty, you've got about two-thirds of the section on that. Parameter uncertainty is almost a third. I don't think you have any slides on that. And there were some things in there that I really want to get into and talk about.

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

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

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

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

MR. McGRATTAN: Right. Yes.

MEMBER BLEY: -- how one deals with that.

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

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

MEMBER BLEY: Okay.

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

MEMBER BLEY: Anything. Sure.

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

MEMBER BLEY: Okay. That's good. I want to put something else on the table that I don't think affects what you have done too much, but I just want to put it out there in case you want to say something about it.

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

MR. McGRATTAN: Yes.

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

All three of the things that you are trying to address here you describe as epistemic, except the experimental, which would be aleatory, and you cover that. So, I think those are all pretty good, but not quite catalogued right. So, that doesn't really affect the guidance here.

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

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

MR. McGRATTAN: Right.

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

MR. McGRATTAN: Right.

MEMBER BLEY: So, all the calculations based on the sigma Es and the sigma Ms, when you get to temperatures out in that range, become a little suspect. Because over half, you know, it is not 5 percent, but 50 percent or more are outside.

MR. McGRATTAN: Right.

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

MR. McGRATTAN: Right.

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

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

But you're right. I mean, you could take these scatter plots and you will find complexity in them. But if we got to the point where, you know, if you said, well, if you are above this temperature, then use these numbers; if you are below this, use these numbers, it became very difficult to put together something that was usable.

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

MEMBER BLEY: I understand.

MR. McGRATTAN: Yes.

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

MR. McGRATTAN: Yes.

MEMBER BLEY: On the other hand, if you get into regimes where the uncertainty is being mischaracterized, helping people learn how to apply expert judgment in those regions, aware of all the evidence underneath it, to give them more honest representation of that uncertainty where the risks might lie out there, it seems to me like it ought to be there.

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

MR. McGRATTAN: Right.

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

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

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

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

(Laughter.)

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

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

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

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

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

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

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

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

MR. McGRATTAN: Well --

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

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

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

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

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

(Laughter.)

MR. McGRATTAN: Let me point out some of

the difficulties we face.

MEMBER BLEY: It does drift, but --

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

MEMBER BLEY: Right.

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

MEMBER BLEY: That's true, it does.

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

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

MR. McGRATTAN: -- wants to look at these plots and say, "You know what? You are using this model to predict the ceiling temperatures in this compartment. I know that you are using the bias and standard deviation that are recommended in general, but we are not comfortable with that. Rerun the numbers for those green dots."

MEMBER BLEY: Yes, you get a new bias.

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

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

MR. McGRATTAN: Right, right.

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

MEMBER BLEY: Okay.

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

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

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

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

MR. McGRATTAN: Right, right.

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

(Laughter.)

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

MR. McGRATTAN: Okay.

MEMBER BLEY: And, yes, maybe the reviewers catch it. But why not help people out a little bit?

MR. McGRATTAN: Okay.

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

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

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

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

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

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

MR. McGRATTAN: As far as different experiments.

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

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

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

MR. McGRATTAN: Right.

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

MR. McGRATTAN: Yes.

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

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

MR. JOGLAR: And what gives us some

comfort --

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

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

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

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

MR. McGRATTAN: We assume they are all unbiased, but, based on the type of measurement that was made, whether the heat release rate was determined through oxygen consumption, calorimetry, or mass loss, we assign greater or less uncertainty to those measurements. And that uncertainty is based on estimates made by the testing labs themselves, who often give rough estimates of the uncertainty in their measurements.

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

MR. McGRATTAN: Right, right.

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

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

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

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

MR. McGRATTAN: Yes.

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

MR. McGRATTAN: Okay.

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

MR. JOGLAR: Well, it is very useful.

(Laughter.)

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

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

MEMBER BLEY: Yes.

MR. McGRATTAN: -- instead should correspond to the green and yellow markings. However, what we found is, when we actually crunched those numbers, what we assigned green and what we assigned yellow wasn't necessarily consistently --

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

MR. McGRATTAN: They were.

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

MR. McGRATTAN: Yes.

MEMBER BLEY: Okay.

MR. McGRATTAN: And also --

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

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

MEMBER BLEY: It depends on where you grew up.

(Laughter.)

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

MEMBER BLEY: That's right.

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

MEMBER BLEY: Okay, but now we have numbers.

MR. JOGLAR: Yes.

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

MR. McGRATTAN: Yes, yes.

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

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

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

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

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

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

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

MR. McGRATTAN: Right.

MR. JOGLAR: So, in a fire PRA application, now there is a tool to address cases where your model predicts something very close to the damage.

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

MR. JOGLAR: Yes.

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

(Laughter.)

MR. McGRATTAN: Right, right.

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

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

MEMBER BLEY: I find it interesting that, even the models I suspect that are intended to be realistic mostly overpredict. There's only a few cases where you underpredict on your last chart.

MR. McGRATTAN: Right.

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

MEMBER BLEY: Okay.

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

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

MR. McGRATTAN: Yes.

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

MR. McGRATTAN: Uh-hum.

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

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

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

MR. McGRATTAN: You are averaging things out.

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

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

MEMBER ABDEL-KHALIK: Right.

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

MEMBER ABDEL-KHALIK: Right. So, that was really the underlying reason for my question. What is the utility of making that comparison for a local measurement vis-a-vis a value predicted by a homogenization model?

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

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

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

MR. McGRATTAN: Right.

MEMBER ABDEL-KHALIK: -- the instrument.

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

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

MR. PEACOCK: Yes, if I can. I think part of it is that the concept --

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

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

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

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

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

MR. PEACOCK: Some things are --

MEMBER ABDEL-KHALIK: -- are homogenized parameters.

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

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

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

MEMBER ABDEL-KHALIK: Right.

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

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

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

Here we have used three different models. Each of these models has highest factor and standard deviation. We are looking at three different quantities: the temperature, the heat flux, and the smoke concentration or optical density near the operator.

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

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

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

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

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

I probably carried it out to too many decimal places.

(Laughter.)

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

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

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

MR. McGRATTAN: Okay.

MEMBER BLEY: Back in the beginning, we started with 1855, going after these things, but, then, we jumped to parameter uncertainty and say that the right way to deal with that is through sensitivity cases. And 1855 doesn't quite agree with that. They give some other ideas.

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

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

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

MEMBER BLEY: Yes, exercise No. 3.

MR. SALLEY: Uh-hum.

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

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

MEMBER BLEY: Okay.

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

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

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

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

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

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

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

MEMBER BLEY: Okay.

MR. McGRATTAN: That is a forward process.

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

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

MR. McGRATTAN: Right.

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

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

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

MR. McGRATTAN: Uh-hum.

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

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

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

MR. McGRATTAN: Again --

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

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

MEMBER SHACK: Sampling from the distribution.

MR. McGRATTAN: And sample from the distributions.

CHAIR STETKAR: Kevin?

MR. McGRATTAN: Yes?

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

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

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

MEMBER BLEY: Yes, right.

CHAIR STETKAR: I mean, it does that.

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

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

MR. McGRATTAN: Time. Time.

MEMBER BLEY: -- run the cases?

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

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

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

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

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

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

CHAIR STETKAR: You are developing, though, self-fulfilling guidance. If you tell people "You don't need to do uncertainty analysis," of course they won't do it. Because here is, yet, another NUREG where the U.S. Nuclear Regulatory Commission says I don't need to do uncertainty analysis, even when I have simple tools that I can use at least in four out of the five models.

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

CHAIR STETKAR: Yes, you are.

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

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

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

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

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

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

MR. JOGLAR: As a practical comment, if we have to run the parameter uncertainty for CFAST in all these scenarios, in the PRA you would do fire modeling if it is going to show this is not damaged. Because you start from the premise that I have damage in all these cables; even in Appendix R you fail the entire room. So, you would only do it if you have no -- it is going to eventually show I have no damage. So, you start, also, following your conservative inputs, your 98 percentiles, according to the guidance. If that gets you there, then that is the answer, and it is also conservatism --

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

MR. JOGLAR: Yes.

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

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

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

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

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

Our concern is this is guidance being produced by the United States Nuclear Regulatory Commission that is not adequately quantifying parameter uncertainty, which is the easier of those two concerns. It just isn't. It is being published in 2012 or 2013 maybe.

MEMBER BLEY: That is not to demean what you have got on modeling.

CHAIR STETKAR: I think you have done a great job on the modeling.

MEMBER BLEY: I think it's great.

CHAIR STETKAR: You have done better than anything I have seen anybody do, except you have dismissed the parameter uncertainty. And the uncertainty distributions are available. NUREG/CR-6850 is pretty careful about characterizing essentially all of the basic parameters with uncertainty distribution.

So, this isn't something that users have to go out and divine out of whole cloth. They are there, the uncertainties. There's a couple that aren't, but they talk about all of the basic parameters they use and the vast majority of the calculations are there. There are uncertainty distributions. So, this is not something that is not documented.

And there are tools. Certainly, for the algebraic models, there are off-the-shelf tools that people can use. They are sort of painless. And at least not to tell someone that you can and should use those tools for the applications that are easy. And as we know, the vast majority of calculations that are done are with those algebraic models in practice because they run fast and they give you the necessary results to kind of get you out of the woods.

And even how you might use them in the zone models, although it is more resource-intensive to do that, but running the model maybe half a dozen times, sampling from the distribution to get a sense of the range of uncertainty.

CFD models are a different beast. You know, trying to provide guidance about how to do it in that context might require some thought.

MR. JOGLAR: Yes, my opinion is that, if the guide comes across as saying not do it or we recommend not to, that is certainly not our objective. So, we probably need to revise that language.

I agree with you that the knowledge and the tools to do parameter uncertainty, it is out there, and probably our guide doesn't have to dwell into a lot of detail on how you do it or anything like that. But perhaps we, probably based on these comments, acknowledge and probably expand our bead on it.

MEMBER BLEY: The process, at least for the algebraic models, is probably easier than doing a set of the calculations you are recommending.

MEMBER SCHULTZ: It would be very direct to do it.

CHAIR STETKAR: There is another reason for this, and that is that -- I think there's two reasons. One is that -- you know, this is my personal opinion -- I think this agency should across the board in any type of analysis be emphasizing the need to explicitly identify and quantify uncertainties. And it is especially true as we go into some of these evaluations of fires and flooding and seismic events and extreme events for which there are broad uncertainties, that the rigor of identifying those uncertainties and trying to really quantify them is something I think needs to be done in the agency. As I said, that is my personal opinion. I am not speaking for the Committee.

The other reason is that a lot of the comments that I think we have all been hearing from the users or the people who are developing these fire models is, well, the uncertainties are so broad, so how can we believe the results of any of this? They always point that the uncertainties are so broad. We need to collect more data because the uncertainties are broad. And yet, nobody is quantifying those uncertainties. It is just a way of saying we can't do anything because the uncertainties are so broad.

Well, quantify them. Let's see how broad they are. Let's see if the uncertainty in a particular parameter is consistently driving the results? And the only way to reduce the uncertainty in that parameter is to run more tests. That is worthwhile.

But, until you do that and find those results, you still have this argument that the uncertainties are so broad and nobody has quantified them. So, that is another bit of kind of my motivation for saying we really ought to be addressing this issue.

MEMBER BLEY: I have two little things more. One is it might have been nice in here, maybe even upfront where you talk about the three kinds of uncertainty, to characterize the experimental uncertainty. It is there if you know what you are looking at, but it is not quite characterized in words that might be helpful.

In the last section on the summary, a couple of things kind of jump out. It might be helpful to do more with them.

Model and completeness uncertainty are closely related. You say that in a couple of places. Now where that is important and needs some thought is when you fall outside of the ranges of allegation, you have to go look for something else to help you out.

And giving some advice about how to think about the completeness issue at that point, when you are looking for what to do when you are outside of that range, I think could be helpful stuff. Now whether that belongs back in Chapter 2 or over here, I am not sure, but it could be somewhere.

There is also a statement -- and this one just kind of triggered me a little -- "The most practical way to quantify the combined effect is compare model predictions with as many experimental measurements as possible," umpty-umpty-umpty-ump.

I am not sure I would say "the most practical way". The most direct way and the most comfortable way, but it is also kind of costly, and you are probably not going to get a whole lot more experiments, at least for a while. I don't know what you have got in the pipeline.

MR. McGRATTAN: Oh, outside of the nuclear community, there are many, many experimental datasets available. We are not lacking for --

MEMBER BLEY: That are applicable, that you could make use of, yes.

MR. McGRATTAN: Correct.

MEMBER BLEY: Okay. So, that might be pretty practical then. So, I am not completely --

MR. McGRATTAN: They don't have to be nuclear. We are talking about fire within a compartment.

CHAIR STETKAR: It doesn't know.

MR. McGRATTAN: It doesn't know about reactors or anything else like that, no. There is a lot of data out there, and I wrote that. And in my opinion, comparing your model with as much experimental data as possible, that is the way to go.

MEMBER BLEY: A couple more sentences for the not-as-well-informed would be helpful for people like me. I think that that is true.

I don't completely understand your second paragraph there. Regardless of the application, the assessment of model uncertainty is the same, and the issue of parameter uncertainty is dependent on the application. And there, the applications you are talking about are for what is this fire analysis being done.

MR. McGRATTAN: Right.

MEMBER BLEY: Which comes clear as you read on.

I am not 100 percent sure I understand the difference in the two there.

MR. McGRATTAN: The difference in the --

MEMBER BLEY: Why is parameter uncertainty dependent on the application? If you had said neither one is dependent, I wouldn't think much about it, but --

MR. McGRATTAN: I am going to let Francisco handle this because there's a lot of discussion about big FM and little FM. Are you familiar with those terms?

MEMBER BLEY: No, I should be, huh?

MR. McGRATTAN: Okay, well, I will have Francisco explain them.

MR. JOGLAR: Well, I have to apologize, but I don't think I know what is the exact question.

MR. McGRATTAN: It is, why does parameter uncertainty, the way we do it, depend on the application?

MEMBER BLEY: See, I didn't understand it, either.

(Laughter.)

MR. JOGLAR: I don't --

MR. McGRATTAN: If you are doing the analysis as part of PRA, I suppose if you are doing the analysis as part of an 805.

MR. JOGLAR: Is that the question?

MR. McGRATTAN: Well, I think that is the answer.

MEMBER BLEY: Why is parameter uncertainty different as you go from application to application? But it is a matter of what we know about the parameters.

MR. McGRATTAN: Because in some fire analyses you choose the mean of all the input parameters; in some analyses you choose these 98th percentiles.

MEMBER BLEY: But that is not parameter uncertainty. That is, am I trying to be more conservative or not?

MEMBER SHACK: And that is a different way to deal with uncertainty.

MR. McGRATTAN: Right, and that is the way it is handled now.

MEMBER BLEY: Right. Okay. If that is what you are saying, that didn't come across to me here.

So, what is a big FM and a little FM, since you brought it up?

(Laughter.)

MR. McGRATTAN: Whether the fire modeling is being used as part of a PRA --

MEMBER BLEY: Oh, okay.

MR. McGRATTAN: -- or whether it is being used in some other way. And there are different rules, if you will --

MEMBER BLEY: Okay.

MR. McGRATTAN: -- for how to treat --

MEMBER BLEY: The idea that these are rules about the conservative level of the analysis didn't jump off the page. What jumped off is saying the parameter uncertainty depends on it. Well, it doesn't. The parameter uncertainty is the parameter uncertainty. It is whether you treat it or not or whether you try to bound it or whether you ignore it or whether you treat it by doing a mean.

MR. McGRATTAN: That is what was meant by it.

MEMBER BLEY: And that, it certainly just didn't come across.

MR. McGRATTAN: Okay.

MEMBER BLEY: So, it is not a complaint about the methodology or anything else.

MR. McGRATTAN: Okay.

MEMBER BLEY: It is just a matter of text. I didn't get that.

CHAIR STETKAR: And by the way, Dennis mentioned it; I have precisely the same comment.

MEMBER BLEY: We didn't trade.

CHAIR STETKAR: I swear we didn't --

MR. JOGLAR: This is the second paragraph on which page?

MEMBER BLEY: The last paragraph of --

CHAIR STETKAR: Section 4.5. There's only two paragraphs. This is the second one.

MEMBER BLEY: It is the last one in the whole section.

I think that's it.

CHAIR STETKAR: Anything more on Section 4?

MEMBER SCHULTZ: Just a general comment. In reading the text, I didn't get this impression. But in hearing some of the discussion today, I did. And that impression I hope doesn't carry forward.

The impression was that in Chapter 3 and then part of Chapter 4 the focus of the document is for the user, the user in performing the modeling evaluation.

Then, in Chapter 4, the uncertainty evaluation or the evaluation of the models was something that the reviewer, the regulator, would pay more attention to in reviewing what the user had done. In the text, that is not how it is presented. It is presented that it is the users' responsibility to determine and justify the models that are chosen, and that involves both the work and the model selection as well as the sensitivity evaluation, the uncertainty analysis, and that as part of the justification.

MR. JOGLAR: Yes.

MEMBER SCHULTZ: I just wanted to make sure that, walking forward, we are not expecting the reviewer is responsible or has the job of determining whether the model selection and justification, the model selection was appropriate. It is the user that needs to pull all that forward.

MR. McGRATTAN: Do you want to comment on that?

MR. JOGLAR: Yes. I think our guide, since Chapter 2, the intent has been I think in

Chapter 2, or at least the process, one of the steps I think at the end is do these uncertainty and sensitivity analyses. And always we have intended that all these methods are for the analysts to cover all the ground, and the regulator will just expect to see that treatment in the analysis. So, I don't think we were intending that these uncertainties are something that will be done by --

MEMBER SCHULTZ: That's fine. And I saw that in the documentation. In some of the phrasing, as we went through the discussion today, I heard something about the reviewer would use this portion of the technology to evaluate whether the user had done it. I wanted to be sure that that didn't carry forward.

MR. JOGLAR: Well, I mean, it is certainly a tool for the reviewer to understand the uncertainties. But our intent is that, as part of your fire-modeling analysis, you would do the sensitivity and the uncertainty.

MEMBER SCHULTZ: That's fine. That's why I asked.

MR. JOGLAR: And also, I think we were always also saying that, as part of a specific application, there is always going to be interaction between the plant and the regulator in terms of what, quote/unquote, "acceptable" for a specific application. But that is, in my view, unavoidable. But our process is intended to be done by the analyst.

MEMBER SCHULTZ: And that is why I agree with Dennis and John that bringing in the analysis associated with the parameter uncertainty would add emphasis to that, put it on the table for the analyst, the user of the tools, to assure that that is also incorporated in the analysis. It is important to do. It gives the analyst the full responsibility of evaluating all of that.

CHAIR STETKAR: Any other comments/questions on Chapter 4?

(No response.)

Good.

You guys want to show us some real models, real analyses, right?

MR. JOGLAR: So, as you may have seen in our guide, the examples are a good portion of it. It was, in addition to the treatment of uncertainty, the source of a number of comments. I will point out that consistency in the treatment of examples and input values within an example, between examples, and between the main body of the report and the appendices, was a source of a number of comments. Even minor differences between "You said 200 and it's 205 here" were a good portion of comments. And we spent a lot of time making sure that our treatment between chapters, between chapters and the appendices, was consistent.

So, another point that took us some time is we solved some of these examples with different tools. And making sure our guidance is consistent and building the proper way of using the models, and the results are interpreted correctly, even that the different tools will not give you identical results, was also an area where we spent quite a bit of time making sure that the guidance was clear.

Okay. So, these examples are typical scenarios in the power plants. We have seen them. We walked them down. On my application side of my work, I saw very similar scenarios to these many times.

The other objective of having these examples is that we wanted to create a consistent template for analysis and review. So, if somebody wants to now do a fire-modeling analysis, they should be able to open up one of our appendices and see a full structure with sections and the kind of information that would be recommended, and maybe we can say expected.

So, we hope that this serves as some consistency, it brings some consistency into the practice of developing these fire models and reviewing, because people know what to expect, what should go in.

And, of course, we paid a lot of attention to the requirements of NFPA 805 and the requirements of the fire PRA standards in terms of fire modeling to make sure our guidance covered that. And we have pointed out in this meeting areas where maybe some additional guidance is necessary. We recognize that, and it has come up in the meeting. For example, we were talking about the maximum expected and limited scenario. But we did try to develop these appendices following the current practices and standards.

You will see that our examples are closely related to that sketch that we presented in Chapter 3. That was qualitative. This is the real thing. This is where we go into detail and solve these with one or more models. We pose a very specific question to answer that is very practical, and we try to offer a solution at the end.

As we have discussed, these are real examples. We didn't select them to match the capabilities of the model or to match the V&V ranges. We picked an example and tried to do the best we can with the tools available to solve them, and our discussion should reflect that.

The first one is the control room for habitability purposes. You see here how the control room looks like. It has a complex geometry. It has intervening combustibles. It has an initial source. It has mechanical ventilation. All of those are real. The size is about the size of a single-unit control room. So, it is all within the range of practical applications.

The second one, it is a typical cable spreading room or switchgear room, and it addresses a fire affecting cable trays. That is by far the most common scenario analyzed, some cables exposed to a fire nearby.

It has the complexity of a number of cable trays, which just by adding a number of cable trays makes this a complex problem in terms of fire modeling. So, that is why we see that geometry there.

Modeling large fires in small rooms, although in a fire PRA we may say fail it. Okay? We have a big fire; let's figure out the frequency; fail it. There are applications where a model may be needed, and we presented an example here where we are trying to evaluate if a wrap is good. It puts the burden on the analyst to figure out the parameters characterizing that wrap. But if it is necessary, we provide an example of it.

Again, you can see that we are using geometries that are not a standard box, and this is intentional, not only because it is real, but it forces us to give guidance on what to do, and the model requires you to set it up as a box, right.

The next one, it is very similar to the sketch where we have a large room, and those are also fairly typical, with complex geometry and targets that are far away. This highlights the ability to use CFD to calculate, let's say, smoke-detection time if the smoke detector is placed far away from the fire, or temperature using a target that is far away. That is the reason, primary reason, we have it.

This is very similar to, Example E is very similar to a cable spreading room in that we walk down where there is a relatively-smaller electrical room inside that bigger cable spreading room. And this is a type of room that you go in and you can't see the ceiling, even the large amount of trays there.

And so, we went to great extents to model it as realistically as possible. I think in this example we even used the FLASH-CAT model to come up with heat release rates for multiple cable trays. So, we are trying to use state-of-the-art in this kind of application.

Finally, the large turbine building fire, you can see the oil tanks there. These primarily are the structural integrity, although we are careful in saying we are just calculating conditions and we are not doing a structural analysis. But in the case that you need to evaluate it, I mean, we give you one of the steps to complete that, which is the fire environment, the fire-generated environment around it.

In the fire PRA standard, there are requirements for evaluating multi-compartment fires, and fire modeling in multi-compartment fires is done somewhat routinely. So, we have guidance on how to build and analyze fires where the impact, the fire-generated condition may go up among different rooms for both detection, target damage, and maybe in some HRA application determining what are the fire conditions in an adjacent room. That example is included also.

And finally, we went through a really challenging one, which is a fire in the containment annulus and how to model those.

So, we think these are not straightforward boxes with a fire. They cover a wide range of applications. Of course, there are more difficult ones. But, for guidance, we think that these examples, for whatever application you have, you should find a very close template in our appendices to start off and give you good guidance for both the people preparing it and the reviewers on how to analyze it with multiple models.

MEMBER BLEY: I hope people use it that way and start off with it, rather than just trying to duplicate it, you know.

MR. McGRATTAN: Okay. What I think I will do here is just walk you through one of these appendices, just to show the process that we go through. And as you read through them, this process is fairly similar case-to-case. So, Dave already introduced the basic steps, and I will just go through them one-by-one.

So, the first step in any fire-modeling analyses is just simply to state in simple terms the objective. In this case, this is the control room scenario, and the purpose of the calculations is to determine the length of time that the main control room remains habitable. In 6850, there is a definition of what that means. Basically, it means that the temperature, heat flux, and smoke concentration have to be maintained below certain critical values.

And we describe the scenario, the most important parts. You know, a nice drawing of the space. We include in here enough detail so that you can model this either with a simple model or with a CFD model, to try to include all the geometry.

Then, we follow that up with one of the most important input parameters, and that is the heat release rate. The heat release rates in all these scenarios is typically taken from 6850. In this case, we are told that we have a cabinet of a certain type. Go to 6850, and the recommended 98th percentile heat release rate is shown in this figure.

There was a supplement to 6850 that got into some of the details about how you actually apply that source of energy in the model. It seems from this diagram -- there's a lot of nitty-gritty here, but this is a problem that has come up again and again. That is, different models have different ways of characterizing the volumetric expanse of the heat release rate. If you put on the cabinet, the side of the cabinet -- you know, we did some calculations where we put it with the CFD model inside the cabinet, just to see what the effect would be.

We also list some of the other important parameters. And here's something that we got that we didn't do well at the beginning. That is, we used a lot of parameters, but we didn't justify or document them very well. So, the second time around, we made sure that we wanted to describe what numbers we were using and where we got them.

A lot of times in fire protection engineering, for example, the rate of diffraction of the heat release rate is about one-third. So, one-third of the energy from a fire is radiated; two-thirds is convected upwards. It is just one of those rules of thumb that we always use.

And we are actually asked to justify that number, like we started out in the beginning, where does that number come from?

(Laughter.)

MR. JOGLAR: And the point Kevin is making is this is the type of review we got. Consultants are very concerned on how they write their reports to make sure there is enough justification so that we can have a positive exchange with the regulator. And that is where I was making the point that consistency, given this kind of comment, is probably going to be increased.

MR. McGRATTAN: Yes.

Next in the process is to select the fire model.

MEMBER BLEY: Since you just brought that up, did you guys get NRR to look at your examples and see what they would say about them?

MR. JOGLAR: Well, they reviewed our report. I mean, Dave, you can probably talk about that better than I can.

MR. STROUP: Yes. Well, we had one member of the NRR staff review it as part of the peer review, the original document, and provide comments. And then, they gave it to one of their contractors who is actually doing the 805 reviews now, the second public comment draft.

MEMBER BLEY: Okay. So, they took a look as if they were reviewing a submitted analysis?

MR. STROUP: Yes. Well, that is -- I won't call it a big difficulty, but that is always an issue, is we try to maintain some level of distance between the research and the regulatory arm. But, at some point, you have got to make that crosswalk, so it comes out working together.

MEMBER BLEY: It would be nicer to look before some poor guy submits one. "What the heck is this?"

(Laughter.)

CHAIR STETKAR: Well, no, that is valid because of some of the things I mentioned earlier. The bridge between the two Divisions is the user who will take this as guidance, process it, and then go to NRR and say, "Well, we used this wonderful guidance."

MR. McGRATTAN: Right. We worried about them taking it as gospel.

CHAIR STETKAR: And they will, yes.

MR. McGRATTAN: Because, as you go through any fire-modeling analysis, you make a lot of judgments, based on your own experience and so forth. We worried, because we are modelers, is this going to become the letter of the law?

We said here we are assuming that we are going to assume the properties of concrete instead of chipboard, when we have the two types of materials in the room. Does that now become the standard, the gospel?

And what we wanted to emphasize more was make an assumption and justify why you are making it.

It is actually more important, the justification as to why you are making that assumption.

CHAIR STETKAR: Well, I think that is what Alex was saying earlier, that the burden is on the user to convince the reviewer that what they have done is adequate for the application. It might not be the perfect analysis --

MR. McGRATTAN: Right.

CHAIR STETKAR: -- but it is adequate for the application.

And as long as the guidance in this document kind of sticks to that same mantra, it should all work.

MR. McGRATTAN: Yes. So, this third section, the selection of the fire models, this is new. In my experience with fire modeling, this is new, where now, before you select that model, you need to look at the scenario that you are going to analyze, and you calculate these six non-dimensional parameters. And you ask yourself, is this model capable of computing in this range of parameters? Has this model been validated for this application?

As I said before, in all eight cases the answer was no for some of the parameters. In this case, there were three of the six parameters that fell outside of the validation space, and it is now up to the user to justify why they are going to use a particular model for this analysis.

And just to give you an example of how that would be done, in one of these scenarios we have no ventilation in the room. So, technically speaking, you can't calculate the equivalence ratio because there is no airflow at all into the room. You get a nonsensical result.

So, how do you know that it is okay to use a particular model for this? Well, you can say, how much oxygen is there in the room, and is there enough oxygen in the room to sustain the fire? And you can do a very simple calculation to say, with this much oxygen, this fire is going to consume this much, and we are good to go. Okay?

It doesn't take much. I mean, what I am showing here on the screen is the justification. It doesn't have to be lengthy, but it has to be something to justify why you are outside the validation space.

Okay. Next --

MEMBER BLEY: You just brought up something that I hadn't thought about before.

MR. McGRATTAN: Yes. Okay.

MEMBER BLEY: I should have.

We have had a few interesting fires, some really widespread, but some in very localized areas, such that you could probably model those pretty well. I wonder, I know we have validated against experiment, but have we tried to validate against any actual real fires out there to see if the models actually perform in the way we think they do from the experimental validation?

MR. McGRATTAN: We have done that not necessarily for nuclear applications, but the World Trade Center is a good example where NIST did the investigation of the collapse of the World Trade Center.

Part of the validation of the model were the thousands and thousands of photographs that were taken. So, as we made predictions of where the fire was and how it progressed over the different floors and around the building, we compared our calculations with these photographs.

I am not aware -- and, Francisco or Mark, you might be more aware of -- have there been investigations, fire-modeling investigations, in the nuclear community?

MR. JOGLAR: Well, Rick, you can elaborate it. But my view of this is this recent effort of collecting all these data is going to help quite a bit on that, because it is going to give us enough information to compare.

So, I don't think the data we have now has enough without going into the plants. Like, for example, there may be an interesting fire in the 1980s, and we have a paragraph describing the event. That may not be enough to do a full comparison with the capabilities of the model without going and maybe interviewing some guy that --

MEMBER BLEY: Well, a couple of the real interesting ones were investigated in substantial detail.

MR. JOGLAR: Right. So, in the real interesting ones that I am aware of, of course, there have been these high-energy arcing faults, and those have been investigated. But, for those, our model capabilities are not there and we treat them elsewhere.

So, some of the interesting ones, we see the effects in our analysis, not necessarily in fire models. So, perhaps, as I said, we have all these good data now; there may be a few that maybe we can do that type of exercise.

MR. SALLEY: Yes, it is a very interesting comment you make. And I go back to when Naim and I originally wrote 1805. We worked with ATF. And we kind of looked at their world versus our world.

In the ATF world, they were always trying to reconstruct an event that happened to prove, yes, this is physical and they're telling the truth. So, that was their world. Where our world was the exact opposite, where you had an inspector out there, and he says, "Here's what can possibly happen." So, we always look at the problem from two different ways. We were looking into the future to see what we predict, where they were trying to look into the past to justify how it happened.

Francisco brings up one other really good point, and that is the high-energy arcing fault. You know, there is a case where we know and we see things. We see San Onofre. We see Robinson. But when I say, "Okay, Kevin, here's some off-the-scale heat release rate for one-eighth of a second. Run me a model," it doesn't work. Okay?

(Laughter.)

We just can't do it. So, we have to look at other things, and we have got other programs. We are going to go for the zone of influence. And then, we have got a whole new experimental program we are going to go international with.

MEMBER BLEY: I was just remembering there were a couple of fires. There was one in the Northeast where the room burned for about a half-an-hour. You know, something like that might be interesting to see how these do against that.

MR. STROUP: Yes.

MEMBER BLEY: Not the investigation, to know how it started and how long it took to --

MR. McGRATTAN: But what would be the metric of success? In other words, what would you compare your model prediction against?

MR. JOGLAR: A better way of making my point, that we will need enough information to say yes.

MEMBER BLEY: Something was not on the PRA.

MR. McGRATTAN: If you had, for example, you know, a melted light fixture or something like that, that might indicate a certain temperature at a certain place, and you could qualitatively compare. I can see how that could possibly be done.

MEMBER BLEY: Essentially, when you did the World Trade Center, you looked at -- I don't know; you might have had to modify your models as you went to match up with what had actually happened there.

MR. WACHOWIAK: That is one of the things that is also on the EPRI fire PRA action matrix starting this year.

MEMBER BLEY: Is it really?

MR. WACHOWIAK: It is to look at the fires that we have in the database and try to get a better understanding of what actually happened during the fire. What was the progression? What was the real heat release rate? And you do that by looking at things like what was damaged and compare it.

But I am not sure we are trying to evaluate the models in that case. I think in that case we are more using the validated models to understand better the parameters that would go into the models. That is the angle we would be taking it there.

So, maybe by taking a fire that happened, if we know what the damage was from that fire, we would use the model, then, to evaluate what type of heat release rate or what mass of fuel burn, and things like that, would have to go into this in order to cause the damage that we observed. So, it is more validating the input parameters rather than validating the models at that point.

MR. JOGLAR: It is not a V&V --

MR. WACHOWIAK: It is not a V&V model. It is a better understanding of what the actual fire was.

MR. JOGLAR: -- in 1824, where we have data to actually do --

MEMBER ABDEL-KHALIK: An empirical fit.

MR. JOGLAR: Yes.

MR. WACHOWIAK: Yes, and it is to gain insights for the fires. But that is one area that we want to look at. Maybe that would help us understand better the propagation of parameter uncertainty and model uncertainty that you would use in a PRA.

That is at least my long-term goal, is to help understand how the total treatment of uncertainty would go into the PRA model versus the issues with picking all the peaks and everything associated with bounding values. Because if you are not going to use the bounding values, you have to have a better treatment of the uncertainty.

MR. McGRATTAN: Okay. Next, once the models are selected, now you need to describe how they are run. And typically, we start with the empirical correlations and move up, depending on if there is a need for it.

So, in this case, it is a situation where we have a closed room with ventilation. There is actually a correlation or the FPA -- the Foote, Pagni, Alvarez Correlation -- or closed ventilated compartment.

As you can see here from this sketch, you know, it requires fairly little input information: ventilation rate, fire size, and the volume of the room. And it predicts a rough average temperature throughout the whole space.

Now, if the only objective of this analysis were to determine the temperature in the room, and the temperature from this analysis were sufficiently low -- and I will leave it to you to describe what that would be; let's just say it was -- then maybe the analysis stops there. Okay? That is sort of the screening approach.

But in this case we are not only interested in temperature. We are interested in heat flux, and we are interested in smoke concentration. So, the empirical correlations don't provide us with all the answers.

So, we move on to the zone models. And these are just some snapshots from the zone model called CFAST showing typical input parameters, how they are put in. The heat release rate is dialed in.

The various parameters that I showed on the screen are put in. And you get a temporal evolution of the upper layer temperature and lower layer temperature in the room.

Now, again, if this doesn't address all of the criteria, or if the analyst decides that this doesn't adequately describe the physics, then the next option is to move on to Example CFD. This is an output from the Fire Dynamics Simulator. It shows the smoke from the cabinet starting to spread throughout the room. So, you can see now that you don't have just a uniform concentration of smoke or temperature, but there is a three-dimensional distribution.

As I showed before, once you have run all these different models, you can assess their uncertainties and calculate probabilities of exceeding the critical values of temperature, heat flux, and smoke concentration. And this is the same plot I showed before. So, in this case, it was the optical density in the case with no ventilation that is a cause for concern. And that is where we might spend extra time in the discussion describing how the different models are handling this.

And here is where we use sensitivity analysis. And I will describe how we do it. In this case, there were two parameters that were very important. One was smoke yield from the fire. That is, the amount of smoke per unit mass of fuel consumed that this fire would generate. And the other was the rate of diffraction, how much of the energy from the fire is radiated.

I mentioned before that we had originally just made some ballpark assumptions for these two values based on our own experience. One I think was 5 percent for the smoke yield, and we used one-third for the rate of diffraction.

But the reviewers called us on that, and they said, "Wait a second. Why are you using those numbers." We said, "Well, these are typical numbers." They said, "No, no, no. We want you to justify them."

So, we went to the SFP Handbook, the Society of Fire Protection Engineering Handbook, and we found for this kind of plastic material on the cables that were in the cabinet we have got a smoke yield of, I believe it was, .17 -- it is a relatively-high smoke yield -- and rate of diffraction of .53, which is considerably higher than about .35, which is what we typically use.

And so, what the advice we give to the user is, since this is the phenomena that is most likely to force the operators from the room, look more closely at these parameters. And so, we did sensitivity analysis to show how much would the evacuation -- or what's the term? How would it change the time to abandonment, depending on whether you used the one-third that you would typically use as opposed to the .53?

So, this is typically how sensitivity analysis is used in practice. I appreciate what you are saying about the propagation of the distributions, but this is typically how sensitivity analysis is used throughout our examples, to look at those parameters that play a critical role in, in this case, causing that room to become uninhabitable.

MR. JOGLAR: And these results, you know, we made the point that these are real applications. This is what I have seen in many control room analyses, where we were saying, if you don't have this purge system, you are going to be forced to abandon it pretty quickly because that is how smoke develops.

MR. McGRATTAN: Right.

MR. JOGLAR: I mean, it's quick.

MR. McGRATTAN: Right.

MR. JOGLAR: It is very quick. And we have seen it, also, in experiments.

MR. McGRATTAN: Right. And how fast, you know, when there is a criteria of three inverse meters for abandonment, these are the two opinions from the zone model and CFD. We looked at, you know, how much would these times shift based on those critical parameters that we input?

MEMBER BLEY: Let me clarify something I said earlier.

MR. McGRATTAN: Yes.

MEMBER BLEY: In this case, I think I wouldn't even call these sensitivity studies. I would call these examinations under two different conditions, each one of which could be modeled in a PRA.

MR. JOGLAR: I agree.

MEMBER BLEY: Yes. So that I certainly wouldn't advocate taking some kind of a distribution on the likelihood of the fans being working and show uncertainty distribution of that type.

MR. JOGLAR: And the way I have seen it is both cases are wrong, and you just pick the worst numbers and see if you can live with them.

MEMBER BLEY: That's the first cut.

MR. JOGLAR: Well, both analyses are there.

MEMBER BLEY: Yes. And if you somehow have procedures or something you were trying to model, you could actually couple those cases --

MR. JOGLAR: Or invoke into the model the need for what is the likelihood that this purge system is not going to operate --

MEMBER BLEY: Exactly.

MR. JOGLAR: -- because of operator activation.

MEMBER BLEY: That is what I was trying to say.

CHAIR STETKAR: But, I mean, in principle, that is a branch point in the PRA model.

MEMBER BLEY: Right.

CHAIR STETKAR: You know, it doesn't affect -- you still have to run both calculations. This just gives you a different time for each of those sequences.

MEMBER BLEY: Right, but that is a nice point because where you would look for distributions on parameters is really dependent on how you were going to model these in the PRA.

CHAIR STETKAR: Right.

MEMBER BLEY: So, the treatment aspect would be different. But if you are looking at PRA, there are some things that are parameters that have a range of uncertainty under essentially all different conditions that you would want to try.

MR. McGRATTAN: Right, right.

MR. JOGLAR: But Kevin made the point we are talking less than 10 minutes -- or less. When we make this point to non-fire people, like in training, they say, "Do you really model for less than 10 minutes?" It is consistent with experiments. Where there is more fire in this room, you see smoke all over the place very quick. And that is why we see really this, what we have --

MEMBER BLEY: That is probably a surprise to a lot of people, 10 minutes.

MR. JOGLAR: Yes.

MEMBER BLEY: Yes.

MR. JOGLAR: But you show them experimental results and quickly they say, "Well...."

MR. McGRATTAN: Okay. And finally, just the conclusion and references. The point here is that, again, a lot of fire model analyses get caught up in a lot of details, lots of plots and graphs. Sometimes they don't answer the question that was posed.

(Laughter.)

And even some of our initial writeups of these scenarios, I mean, someone again called us on it and said, "But the point was, and then you are talking about all these other details." We were talking about these details. We thought they were interesting.

(Laughter.)

"Answer the question. What is the answer? When do we have to abandon this room?"

CHAIR STETKAR: Take that approach and convolute it with electrical engineers, who just love to run little analyses of 37-conductor cables, and all the different combinations --

MR. McGRATTAN: Right, right.

CHAIR STETKAR: -- there's your problem.

(Laughter.)

MR. McGRATTAN: Yes, and if you have spent time on these things, you want to present it. But that often, as I said -- when Francisco is doing his hundreds, or even thousands, of analyses, you know, it is hard to work through thousands of pages of analysis.

So, we want to emphasize with these examples as a template that you don't have to write a 10-page conclusion. If you've got good justification for your answer, you know, maybe this is all you need.

MR. JOGLAR: Or you don't have to have 250 columns of output out of the model. We, hopefully, give enough guidance to say, "These are the ones you pick to solve this issue."

MR. McGRATTAN: Yes, yes.

MEMBER SHACK: Your last sentence versus the table, I thought CFAST, in fact, predicted that you would have to abandon.

MR. McGRATTAN: This is addressing the case were the purge system is on. So, there's two scenarios here that we are looking at. One is in which the purge system is on. That is pulling smoke out, pulling smoke out of the room. And there's another scenario in which the purge system is turned off. Essentially, there is no ventilation. It is the case where there is no ventilation where the room simply fills up with smoke and it becomes uninhabitable.

So, we are actually making the case, if you did have the purge system on, it would remain, I believe, if I recall, that it would remain habitable.

MEMBER SHACK: A .36 probability.

MR. McGRATTAN: Yes. Yes. And then, the .36 probability is something that the reviewer can take in the sense that, however he or she or she wants --

MR. JOGLAR: Yes, and it is done in the PRA. This is a chance to get out and you model that as a branch in your analysis. I mean, we discuss other reasons to leaving.

CHAIR STETKAR: Any other questions on the example?

MEMBER SHACK: How well did your scaling for the sensitivity match in this case? Was it linear, as it is predicted in the table?

MR. McGRATTAN: Well, in this case it is linear because we are just transporting the smoke and it is not depositing on the wall. So, it is perfectly linear. In reality, it is not perfectly linear because it does deposit on the walls.

MR. SALLEY: I can just do it from the side. Give me the slide, Kevin.

CHAIR STETKAR: Just make sure you are near a microphone. Speak into the microphone.

MR. SALLEY: Yes. We timed it pretty good there. I think we had it until 5:30. So, we've got a little more time if you want to catch anything else, and I would more than welcome that. Plus, we need to stay later.

The bottom line is you can see the

timeline of this project, the history of it. For where we are at, we believe that this is pretty much ready for primetime.

Yes, we did get some good comments out of you. I think we do need to make some adjustments. Is that a fair statement to you guys?

MR. JOGLAR: Repeat it again, please?

MR. SALLEY: We did get some good comments here today, and I think we do need to make some adjustments to the document. But I feel pretty comfortable overall that we can make those adjustments. Rick and I were talking. Is that the thought of the team?

MR. McGRATTAN: The issue of sensitivity analysis, I don't think that is trivial.

MR. SALLEY: I didn't say "trivial". But I think it is a solvable problem. It is solvable --

MR. McGRATTAN: Everything is a solvable problem, but I think that that sensitivity analysis needs to be looked at carefully, in light of the fact that in a lot of these scenarios we have chosen sort of the 98th percentile fire. I am not sure what it means in that context to propagate, for example, the distribution of heat release rates. That is a different analysis.

MR. JOGLAR: If I understood the point, it is that we are missing guidance on parameter uncertainty. I think we were in agreement that this is a solvable issue, that the tools are there. I think it is well-covered in the literature. So, I don't know how -- you know, to recognize it and to give guidance, I believe that we can get to a place that that can be done.

MR. McGRATTAN: We would want to show it in the examples, how we would do this.

CHAIR STETKAR: You guys can sort of work this out among yourselves, I think.

(Laughter.)

MR. WACHOWIAK: There was nothing that I saw that was outside the scope of what we have in the document. The sensitivity is probably the more difficult of the ones to do, and we just need to see how we can do it within the scope of the project that we are working on. I think we understand your comments there. It is not the instructions for how you plug this into your fire PRA uncertainty analysis. It is a look at what would an analyst do to address parameter uncertainty, and I think we can provide some examples of that.

Anyway, so, we will talk about it amongst ourselves, but I didn't see any showstoppers. I agree with Mark.

MR. SALLEY: Again, I think that is the key. I don't think there's any showstoppers. This is a pretty good document. I will stand behind this document. It has been through the process.

We will make the changes. We will bring the team back together in the next couple of weeks, Dave, and have a few more meetings, do some of the things we talked about.

And again, we want to request a letter from you, John, to go forward and publish this.

CHAIR STETKAR: There's a couple of things I need to do before we wrap up.

MEMBER SHACK: When are you coming back to the full Committee?

CHAIR STETKAR: They are coming in May.

MR. SALLEY: May is what we were going for.

CHAIR STETKAR: And I want to talk about that. But there's a couple of other things I need to do here.

First of all, I have to ask this: are there any members of the public here who want to make any comments?

(No response.)

And I believe we have a bridge line open. I have to give people --

MR. BROWN: The bridge is open.

CHAIR STETKAR: The bridge is open. There's somebody out there. Excellent.

Is there anyone on the bridge line who would like to make any comments or statements or have any questions? Is there anybody out there? Say something so we know definitely it's open.

PARTICIPANT: Yes, I am out here. I can hear you guys. Can you hear me?

CHAIR STETKAR: Thank you. That's wonderful. Confirmation is good.

PARTICIPANT: Okay. I don't have any comments.

CHAIR STETKAR: Great. Thank you very much.

We will reclose the bridge line then, just so we are not disturbed.

And what I would like to do first is to go around the table and see if any of the members have any further comments or questions.

And then, Mark, what I would like to do is explore, do you still want to come in May.

MR. SALLEY: Yes.

CHAIR STETKAR: Okay.

MR. SALLEY: Yes. And just to close out my slide there, John -- and I will turn it right back to you -- if you look at the time we have invested in this, there's other things that need to be done. Okay? We saw doing this, talking parameter uncertainties, that we need to catalog a lot of the parameters, the k-rho-Cs for different materials, things of that nature that the modelers are going to need. We would like to do that as a supplement to this.

The V&V, you brought up two excellent points. Since we have done that V&V, we have created new tools, you know, FLASH-CAT and THIEF being two of them. And we are going to make more. We need to go back to that V&V.

NIST has located a lot more experimental data out there that we can use to expand that V&V, and these are the kind of things that we want to do. One of the things with the experimental stuff, to answer a question earlier about the different labs, when we did the original V&V, you should have seen how many experiments we threw away. I mean, a lot of people gave us a lot of experiments, and we went through them and we started saying, "What's the quality of this?" And we couldn't trace quality back. It is like, "Sorry, we can't use it because you introduced too many uncertainties into our validation."

So, again, since that, in the spirit of working together, I know Kevin and Rick have spent a lot of time looking through a lot of other catalogs of experiments that we can bring in. The bottom line is we need to get over this hurdle to get back to the V&V and get on with it.

So, with that, John, I will turn it back to you.

CHAIR STETKAR: Okay. Let's go around the table, and I still want to make a couple of comments on what we see as the full Committee.

Bill, any comments? Any further questions?

Said?

MEMBER ABDEL-KHALIK: Well, I have sort of a big-picture comment. Looking at the incremental effort that an analyst would have to go through going from his own model to a CFD model, have you thought developing some kind of intermediate step between these two, where instead of having a two-zone, single-compartment model versus a detailed CFD model with thousands or tens of thousands of nodes, maybe coming up with a multi-zone, multi-compartment model where not all zones are the same? There are different types of zones that one can incorporate in sort of more of a macroscopic model.

MR. McGRATTAN: A zone model will have different conditions and different compartments.

MEMBER ABDEL-KHALIK: No, no, no. I understand. But within a single compartment you can have different types of zones.

MR. McGRATTAN: There is a model that was developed in Germany called COCOSYS. It was one of the models that was evaluated in this -- there was mention before of this benchmark exercise, international collaboration. The Germans had this model called COCOSYS.

It broke up a single compartment into a couple of dozen zones. But in my opinion the problem with that approach was that they never got beyond all of the questions and concerns that bedevil zone models.

Most of the people who participated in this said, well, if it takes an hour to run COCOSYS and a day to run a CFD model, that wasn't considered a big enough reason to develop this so-called hybrid model. That was just the impression, that it still had too many of the limitations of a zone model, because you didn't really have a true fluid, you know, a faithful fluid dynamics solver.

MEMBER ABDEL-KHALIK: It just seems to me that there is sort of almost a three-order-of-magnitude difference in amount of effort required for one model versus the other. And there has got to be some reasonable intermediate step that would give you enough resolution for what you need without having to make that amazing jump in common effort.

It seems worthwhile to at least explore. Because, you know, you can define a model in terms of volume elements and boundary elements, and they are not the same. You can build a model from a limited number of volume elements and boundary elements that would allow you to come up with enough resolution to understand what is going on.

MR. JOGLAR: In my opinion, that is the reason the zone models are still alive, because it was the bridge between the hand calc and the CFD. So, I understand your point.

CHAIR STETKAR: Any more?

MEMBER ABDEL-KHALIK: No.

CHAIR STETKAR: Dennis?

MEMBER BLEY: Yes. In spite of maybe what it sounded like, I was really pleased reading this draft. I think you guys have done a heck of a job. I think the work on modeling uncertainty is really helpful.

Many of the things I talked about I think could be addressed with some relatively-limited additional text to provide cautions and guidance and direction to folks.

But congratulations. I think you have done a nice piece of work here.

CHAIR STETKAR: Steve?

MEMBER SCHULTZ: Yes, I just have one comment. That was that I was struck by the opportunity that you had and used to adopt comments, get comments and then adopt the comments through the workshop and training programs that have taken place recently in the last year, and used those as a part of document development. That certainly has been a great addition to improving not only the technical portion of the document, but the presentation of it. So that it comes forward as a very understandable and user document that has some strength of practice and purpose behind it.

So, I was pleased to see that and

certainly would encourage that in documents that are associated with user documents in the future. I think this is an excellent example of how one develops a document for the user, by bringing it forward to the training program and gaining from the experience of the user in finalizing the documentation. So, that has been a great help here.

Other than that, John, no further comments.

CHAIR STETKAR: Thank you.

I would also like to say I think this is a really good document. I do think, and echo Dennis, I do think it needs a bit of work in a couple of areas. We have mentioned those. I will summarize them.

I think a little bit better guidance about what to do when your scenario exceeds the V&V bounds. We talked quite a bit about that.

And some treatment of parameter uncertainty and guidance about how one might do that within the regimes of the three different categories of models.

But, other than that, I would echo, I think the modeling uncertainty is really good. I think that the practical examples and qualitative guidance that you have in there for a user on decisions about what types of models to use and limitations, I think it is really, really good.

Mark, the only thing I would say as far as the full Committee meeting --

MEMBER SHACK: Plus your spurious actuation question.

CHAIR STETKAR: Oh, yes. I'm sorry. Thank you.

(Laughter.)

I ranted long enough. I figured they picked that up from that section on multiple spurious operations. But that also, that is text-writing. It isn't fundamental technology. It is just acknowledging how that is treated in the risk-informed world, instead of just the deterministic focus.

And change the sign in that one equation.

MEMBER SHACK: Parameter uncertainty, I mean, sometimes that is sort of dictated by the guidance that you have. I mean, if it says use the 98th percentile, you use the 98th percentile.

CHAIR STETKAR: That being said, and, indeed, most of the deterministic -- either the deterministic uses of the firewalls, and they are used in the deterministic analyses, pretty much say that, and the screening guidance for using fire models says, as a way of screening out areas or fire scenarios for further evaluation, and the risk-informed does that.

But a lot of the people in NFPA 805 applications are going to be plucking mean values, running some sort of fire model, mean values from the parameter uncertainty distributions, running the fire models, whether algebraic or zone models, anyway, and presenting the results as, "Here is my answer."

And they are doing that. They have done that in the pilot studies. They are doing that in --

MEMBER SHACK: They always do it.

CHAIR STETKAR: And the thorniest issues are going to be handled that way. So, I think that the parameter uncertainty is a relevant topic for the things that survived into what the NRR folks are going to be reviewing.

One thing I did want to mention, Mark, is for the full Committee meeting I am presuming that, given the timing because you are on the schedule for May, that what the full Committee will be reviewing will be the document that we have. Is that correct? Or are you planning to change it?

MR. SALLEY: I'm planning to change it. I hope my team is behind me with that.

CHAIR STETKAR: Well, if you change it,

recognize that today is March 21st --

MR. SALLEY: Right.

CHAIR STETKAR: -- and we need that document 30 days before our full Committee meeting.

MR. SALLEY: Okay.

CHAIR STETKAR: So, you don't have much time to make the changes.

MR. SALLEY: When is the May meeting?

MR. LAI: May 11th.

MR. SALLEY: April 11th?

MR. LAI: May 11th. So, you need to get it to me by April 11th.

CHAIR STETKAR: Just keep that in mind because we do need that 30-day lead time. We don't want to get into the situation where we are discussing something that is a moving target at the time of the meeting.

MR. SALLEY: I want to give you the final document, John.

CHAIR STETKAR: Yes. Okay.

MR. SALLEY: And then, that is what the team will strive to do. Then, I think we are going to focus-in on that and try to deliver that to you.

MEMBER ABDEL-KHALIK: Can we get a copy with track-changes anyway? So that those of us who sort of sludged through this would not have to go through the whole thing hunting for changes?

MR. SALLEY: If that would help you, we would be happy to do it.

CHAIR STETKAR: Just work with John and make sure.

The only message I wanted to get across is that, if we have that May meeting, I don't want to be in a situation to say, "Well, we're still finishing up a few paragraphs in section" whatever.

MR. SALLEY: These are the fire modelers, not the HRA group.

(Laughter.)

CHAIR STETKAR: That is on the record.

(Laughter.)

That being said, I would like to thank the staff and everyone.

I thought that it was a really good presentation. I think we had a good exchange. I think there is a clear path to getting this thing out in a timely manner.

With that, we are adjourned.

(Whereupon, at 5:24 p.m., the meeting was adjourned.)

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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 Branch

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

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- 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)

Fire Modeling Team

- 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 Regulatory Research

Fire Research Branch

Purpose of Report

- Focused on User
- Not a Replacement for Model User's Guide
- Practical Applications
- Training
- Quantify Uncertainty

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ACRS Recommendations

- NFPA 805
- NUREG-1824/EPRI 1011999 Review
- User's/Application Guide Needed
- Estimates of Ranges of Parameters
- Quantitative Estimates of Uncertainty

Public Comments

- 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

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Chapter 1

- Background Information
- User Capabilities
- Basic Theory
- Report Organization and Objectives

Chapter 2

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

Fire Research Branch

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

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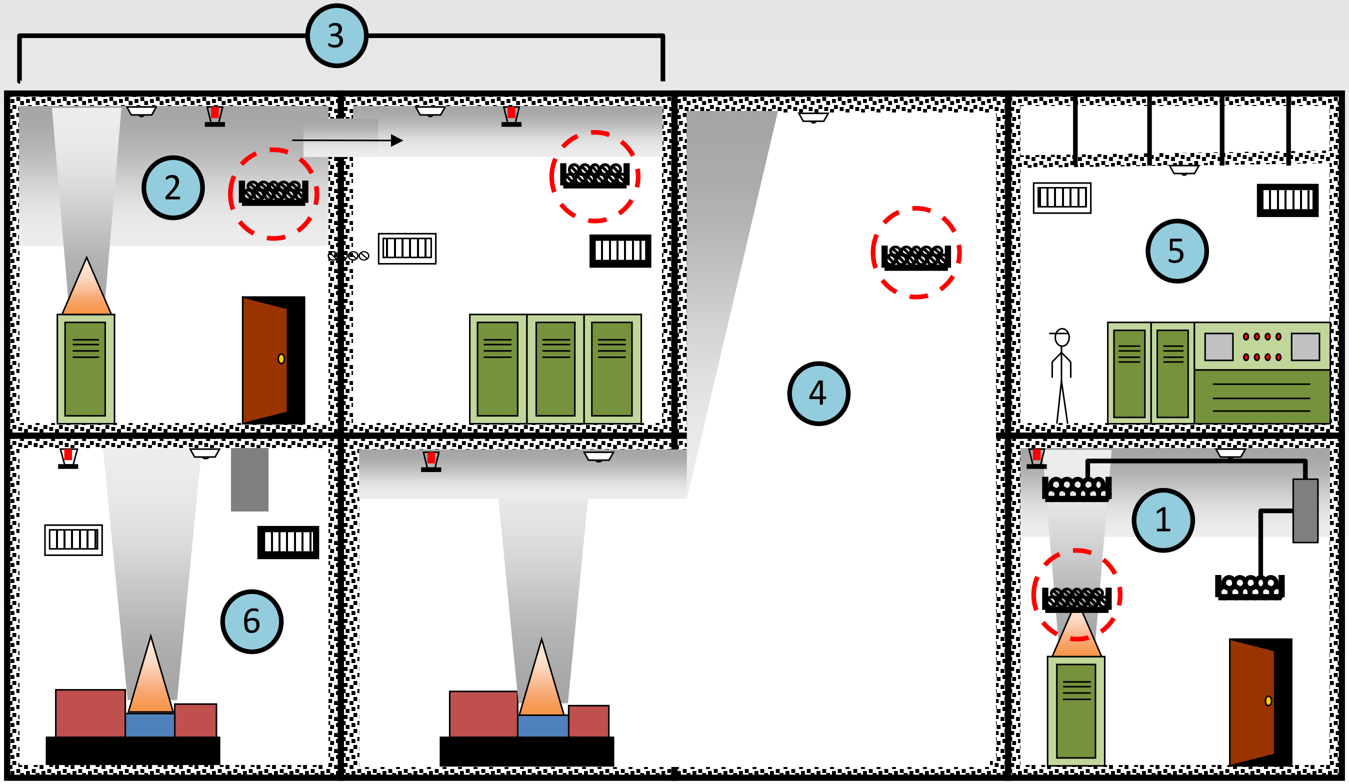
Scope

Figure 3-1. Pictorial representation of fire scenarios.



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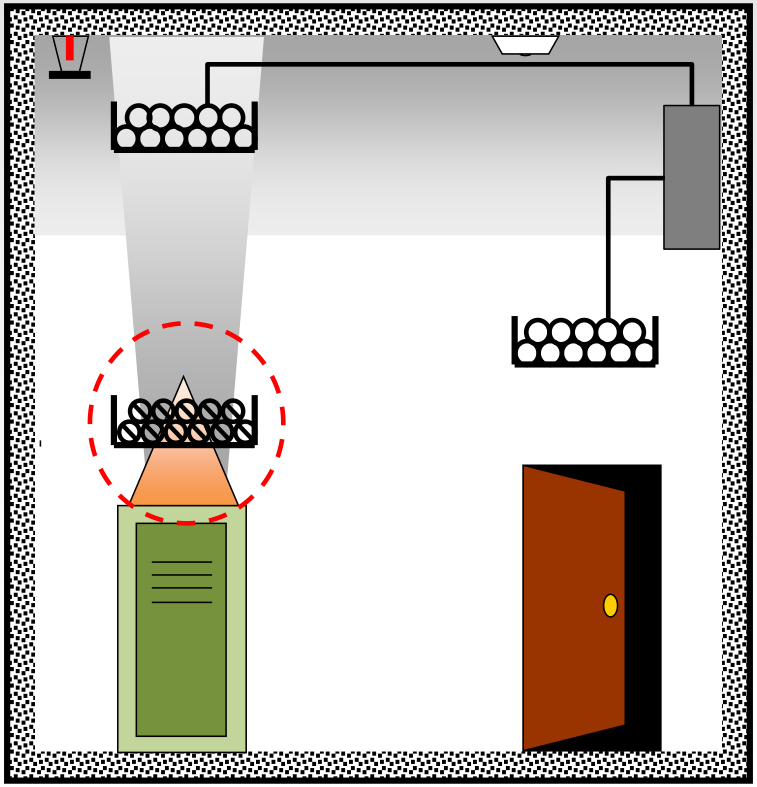
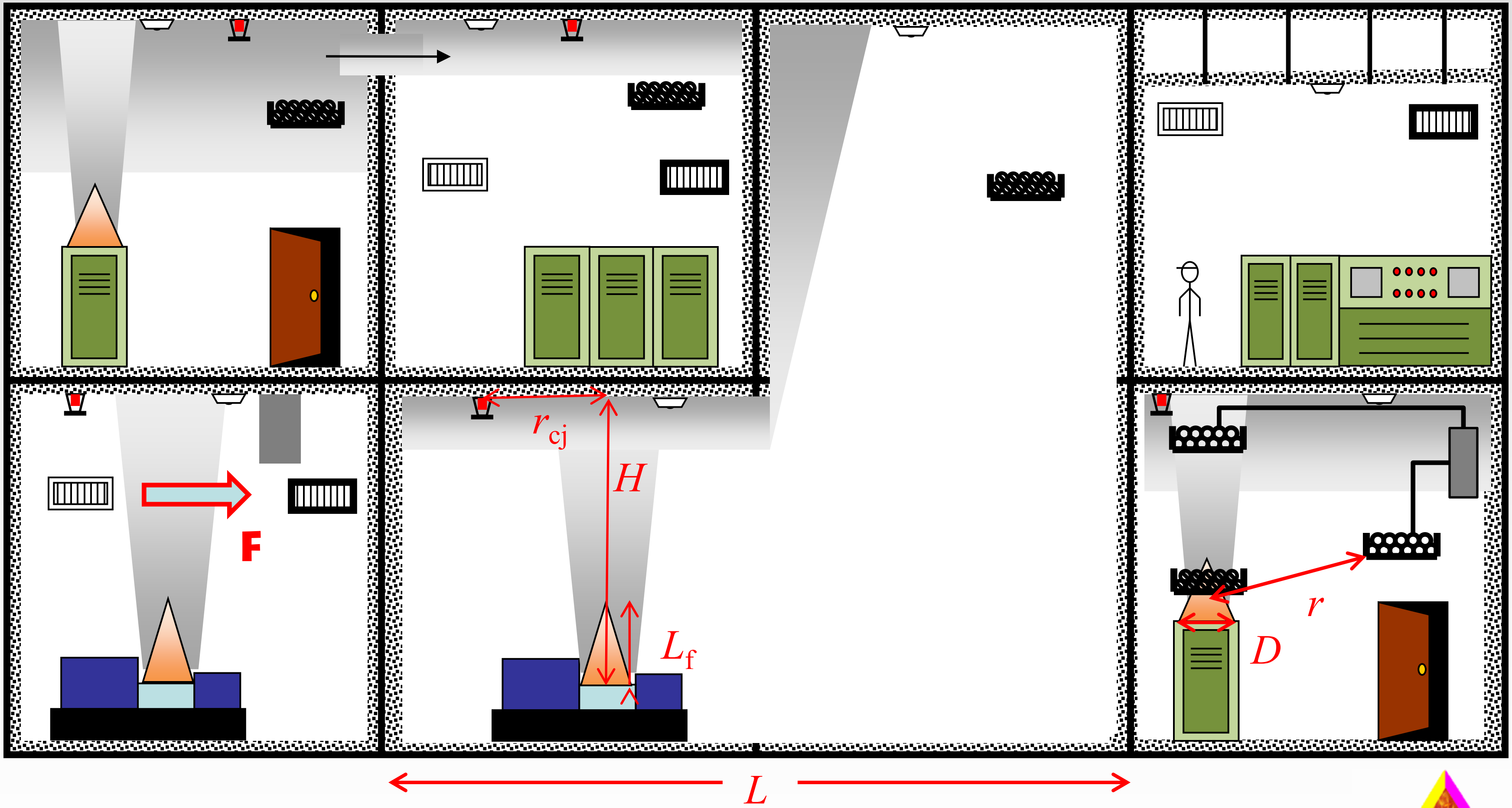
Fire Research Branch

Example

Scenario 1: Targets in the Flames or Plume

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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)

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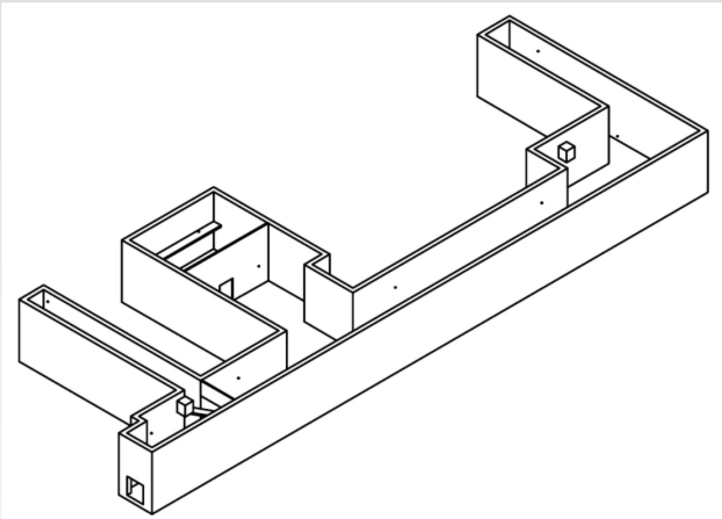
Example of Sensitivity Analysis



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.

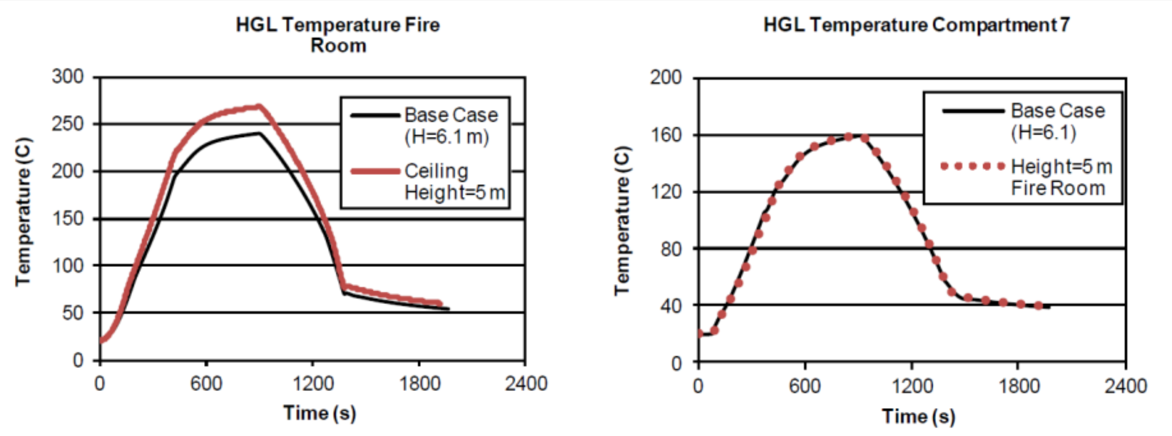


Figure G-10. Hot Gas Layer Temperature for Reduced Ceiling Height by MAGIC.

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 Branch

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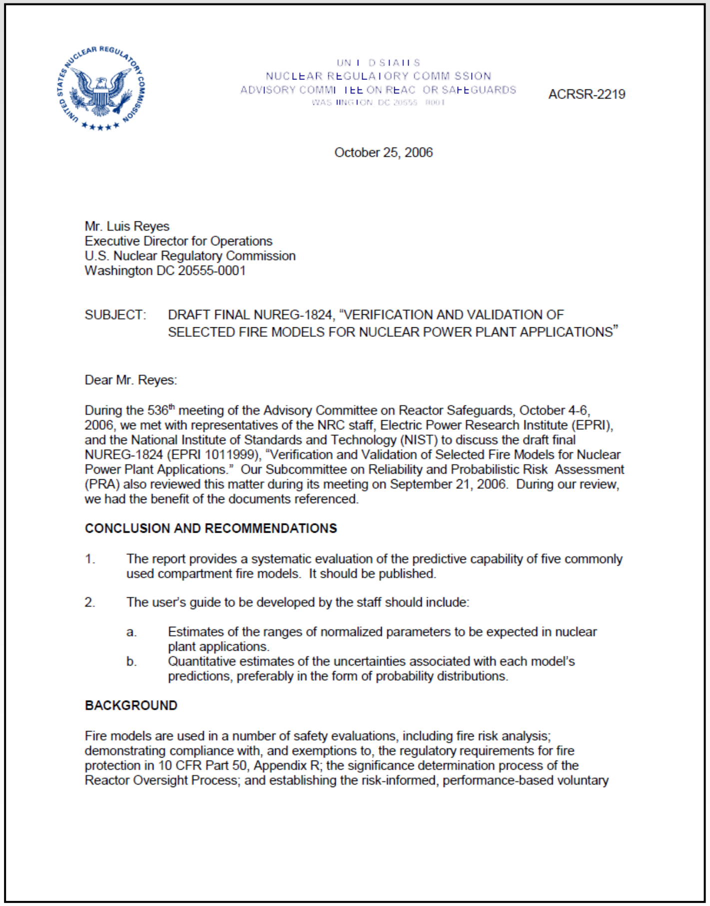
ACRS Review of NUREG-1824



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 536th 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:

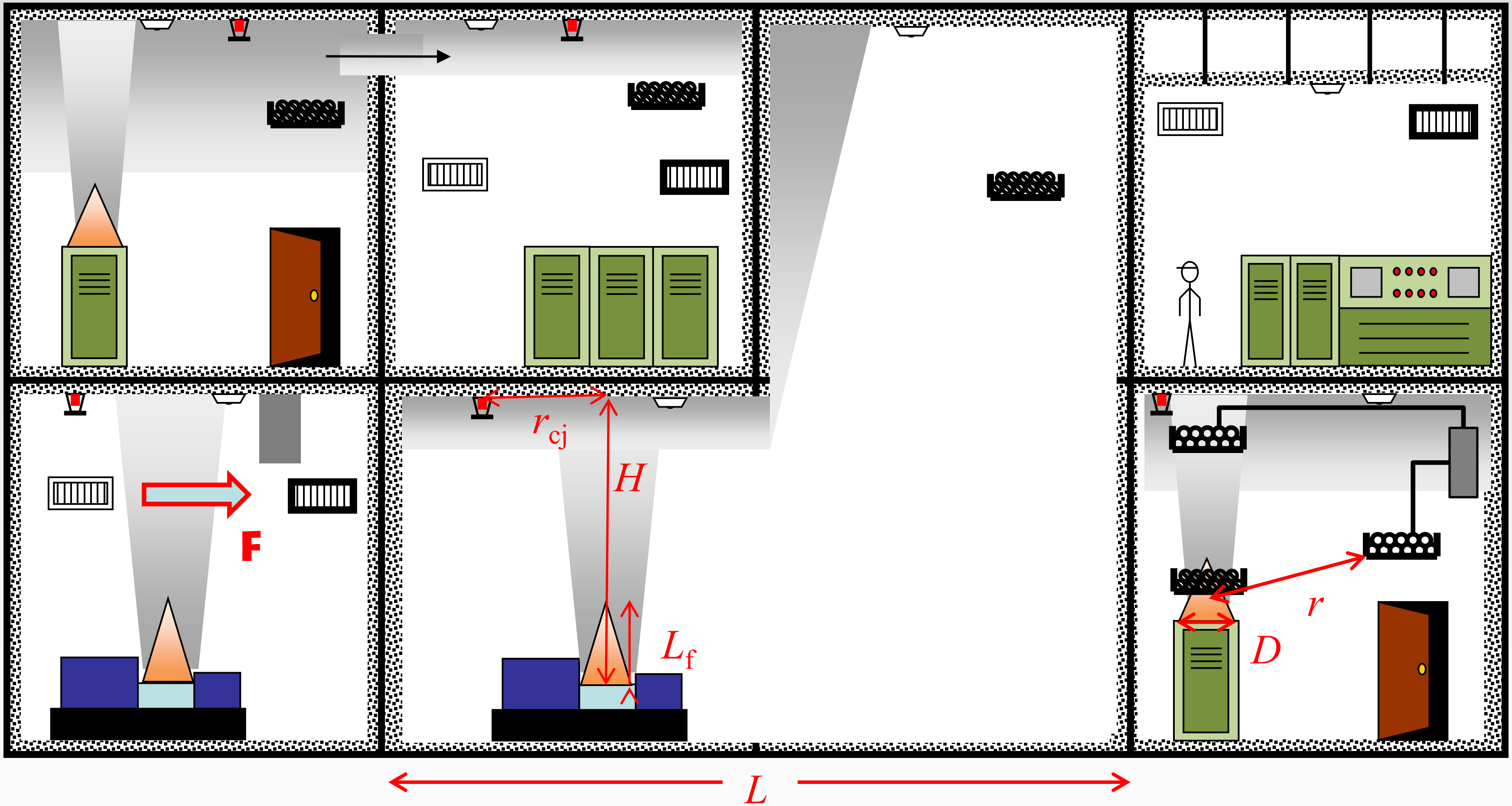
   a. Estimates of the ranges of normalized parameters to be expected in nuclear plant applications.
   b. Quantitative estimates of the uncertainties associated with each model's predictions, preferably in the form of probability distributions.

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

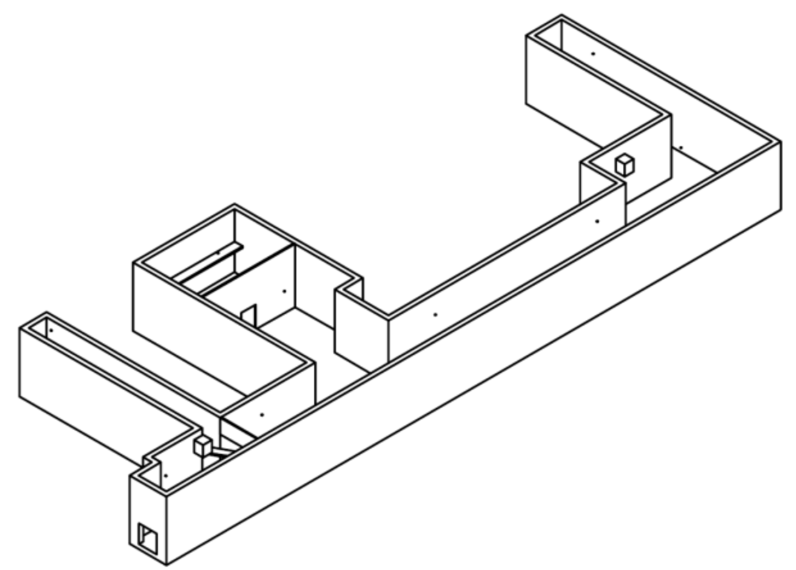


What to do if the scenario is out of the validation range?

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



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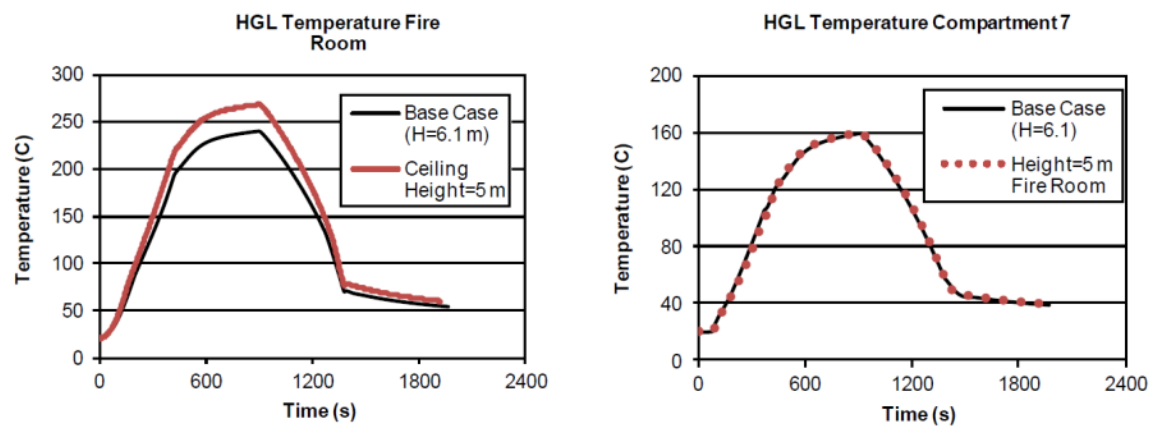

Figure G-10. Hot Gas Layer Temperature for Reduced Ceiling Height by MAGIC.

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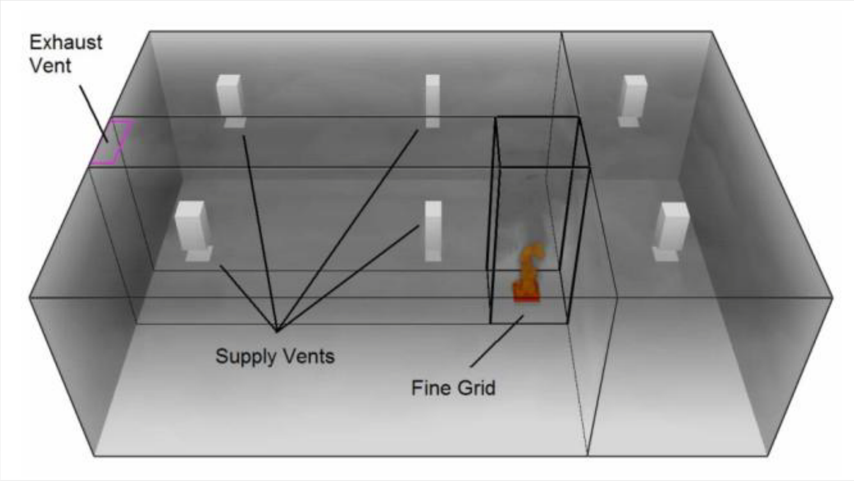
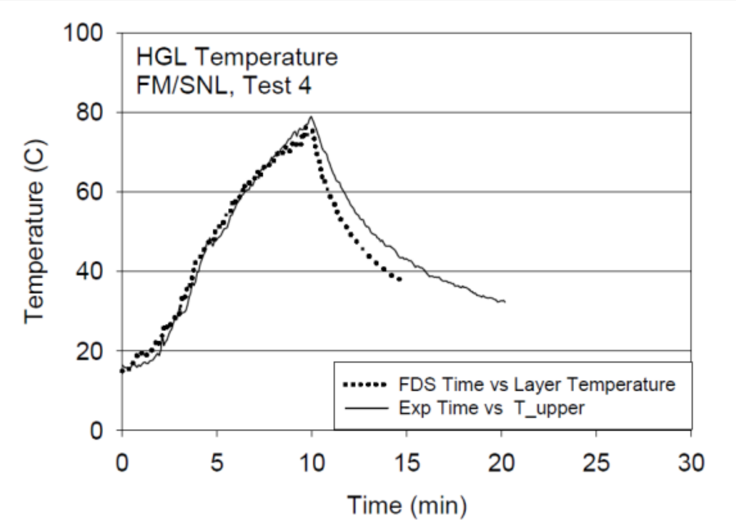
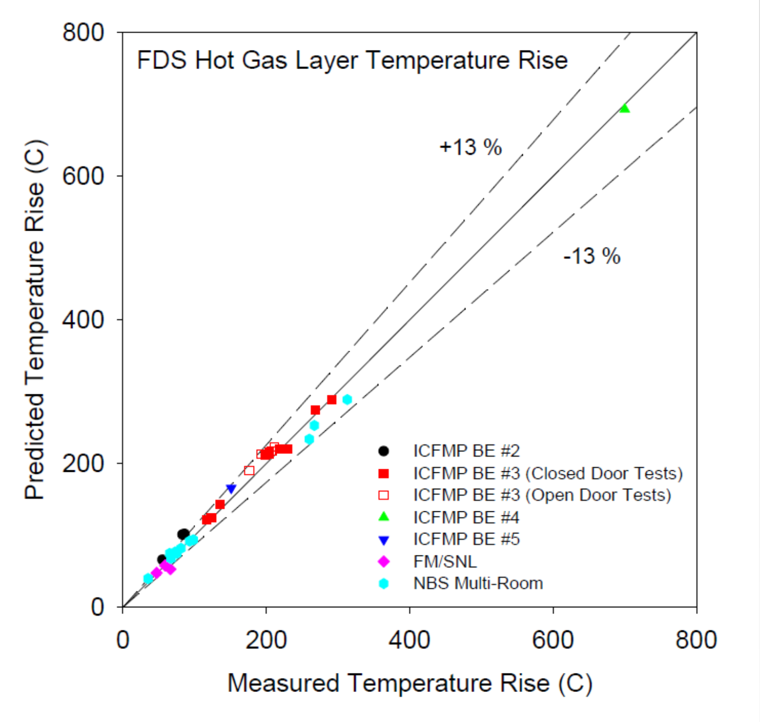
Types of Epistemic Uncertainty (NUREG-1855)

- 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

Electric Power Research Institute
3420 Hillview Avenue
Palo Alto, CA 94303

Table 3-1: Results of the Validation & Verification of the Selected Fire Models for Nuclear Power Plant Fire Modeling Applications

Parameter[5]		Fire Model				
		FDT[s]	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+[2]	YELLOW+	GREEN	GREEN
Plume temperature		YELLOW–	YELLOW+[2]	N/A	GREEN	YELLOW
Flame height[3]		GREEN	GREEN	GREEN	GREEN	YELLOW[1]
Oxygen concentration		N/A	N/A	GREEN	YELLOW	GREEN
Smoke concentration		N/A	N/A	YELLOW	YELLOW	YELLOW
Room pressure[4]		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

ACRS Review of NUREG-1824

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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 536th 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

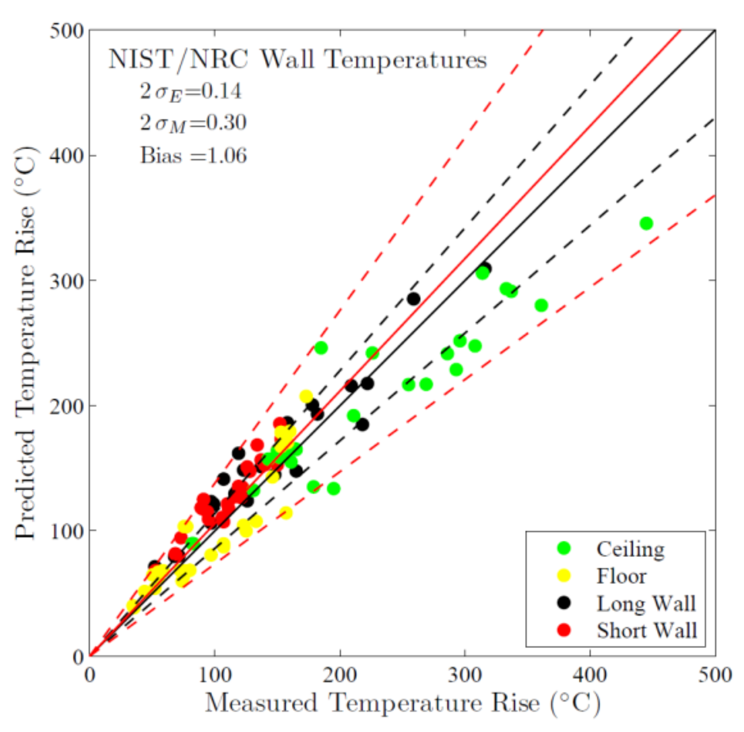
The user's guide should also provide probability distributions for the model predictions due to the intrinsic model uncertainty, i.e., the uncertainty associated with the model's physical and mathematical assumptions. These distributions should not include the uncertainties in the heat release rate since 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).

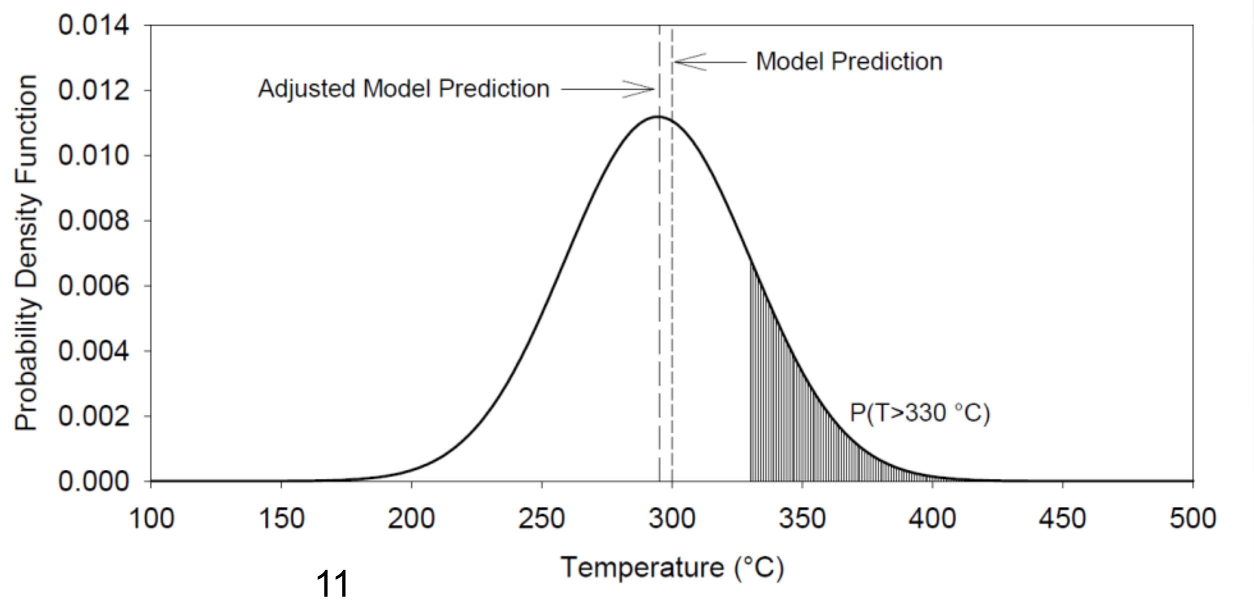
Output Quantity	FDTs		FIVE		CFAST		MAGIC		FDS		Exp
	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	$\tilde{\sigma}_E$
HGL Temperature Rise*	1.44	0.25	1.56	0.32	1.06	0.12	1.01	0.07	1.03	0.07	0.07
HGL Depth*	N/A		N/A		1.04	0.14	1.12	0.21	0.99	0.07	0.07
Ceiling Jet Temp. Rise	N/A		1.84	0.29	1.15	0.24	1.01	0.08	1.04	0.08	0.08
Plume Temperature Rise	0.73	0.24	0.94	0.49	1.25	0.28	1.01	0.07	1.15	0.11	0.07
Flame Height**	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.
Oxygen Concentration	N/A		N/A		0.91	0.15	0.90	0.18	1.08	0.14	0.05
Smoke Concentration	N/A		N/A		2.65	0.63	2.06	0.53	2.70	0.55	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	0.59	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

$$P(x > x_c) = \frac{1}{2}\,\mathrm{erfc}\left(\frac{x_c - \mu}{\sigma\sqrt{2}}\right)$$

Model Prediction

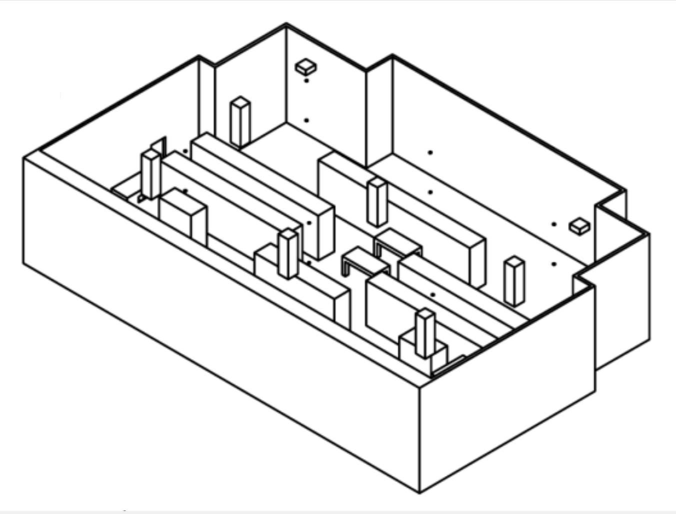
$$\mu = M/\delta$$

Model Bias

$$\sigma = \tilde{\sigma}_M(M/\delta)$$

Model Standard Deviation

How Model Uncertainty is Applied



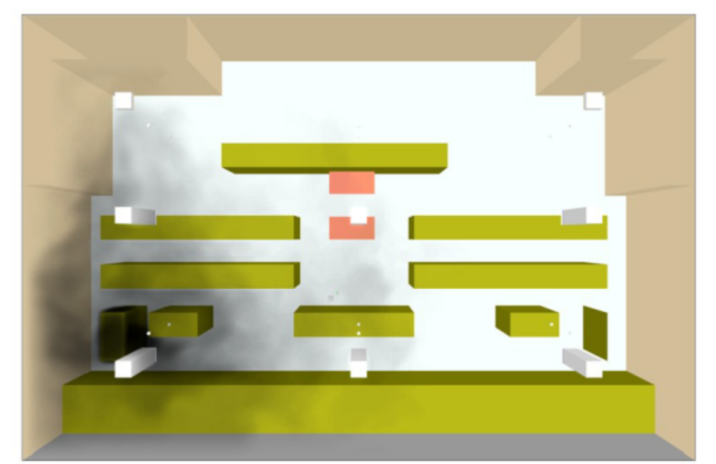


Table A-4. Summary of the model predictions of the MCR scenario.

Model	Bias Factor, δ	Standard Deviation, $\tilde{\sigma}_M$	Ventilation	Predicted Value	Critical Value	Probability of Exceeding
Temperature (°C), Initial Value = 20 °C						
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
Heat Flux (kW/m^2)						
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
Optical Density (m^{-1})						
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

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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

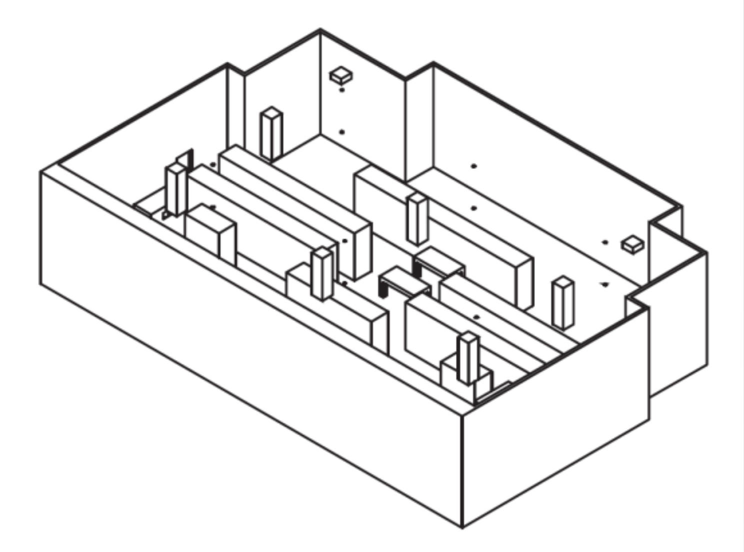
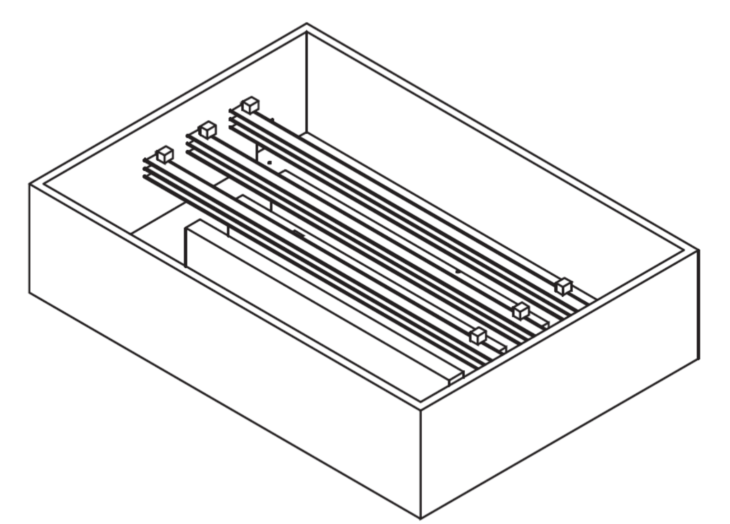


Figure A-11. FDS/Smokeview rendering of the MCR, as viewed from above.

B. Cabinet Fire in a Switchgear Room



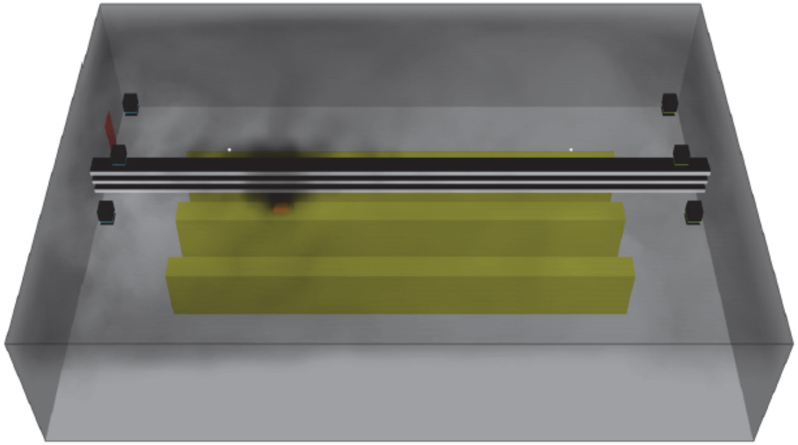
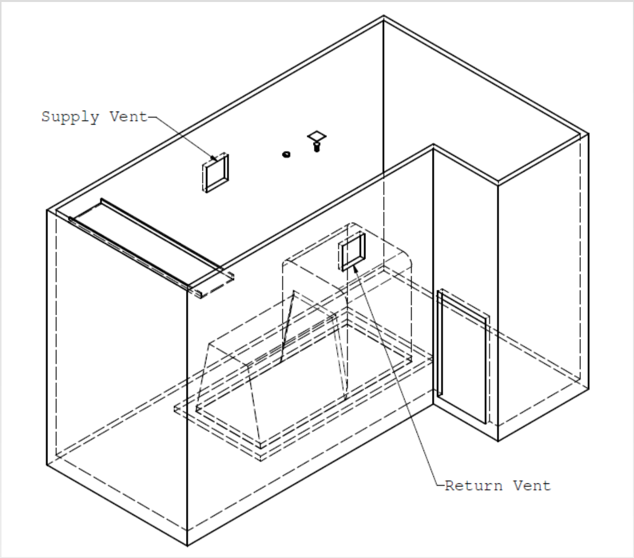
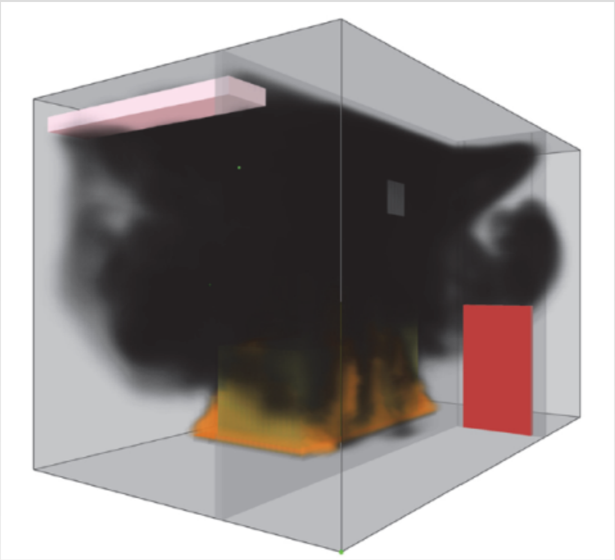


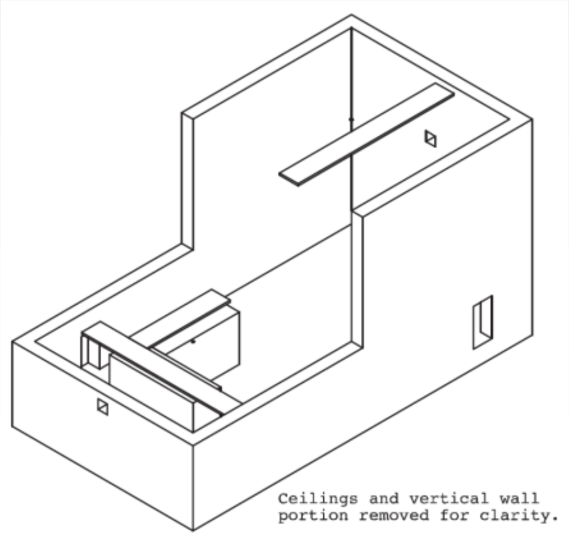
Figure B-10. FDS/Smokeview rendering of the switchgear room.

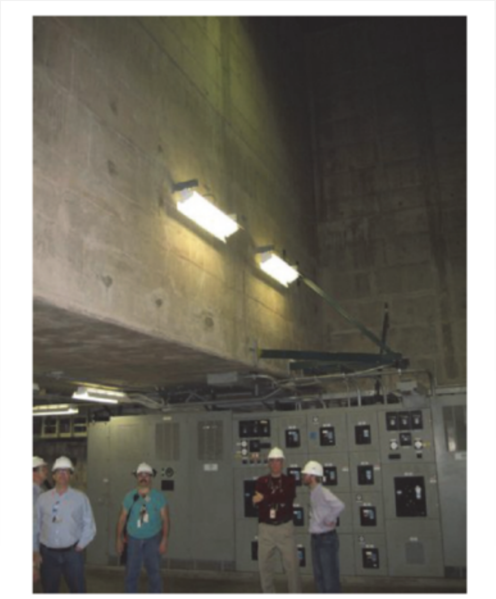
C. Lube Oil Fire in a Pump Room



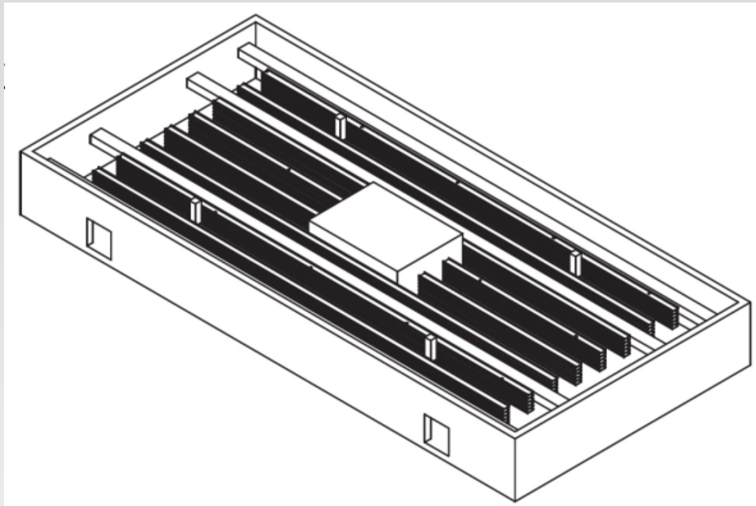


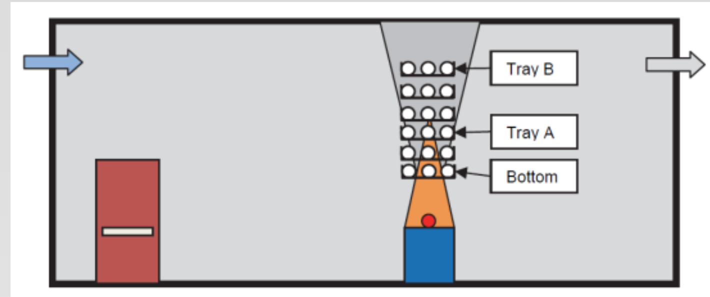
D. Motor Control Fire in a Switchgear Room



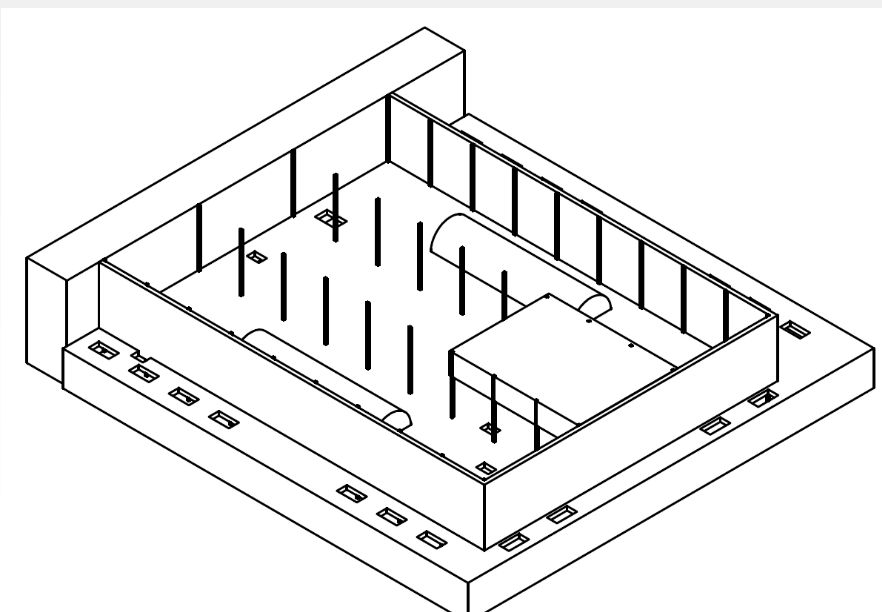


E. Transient Fire in a Cable Spreading Room

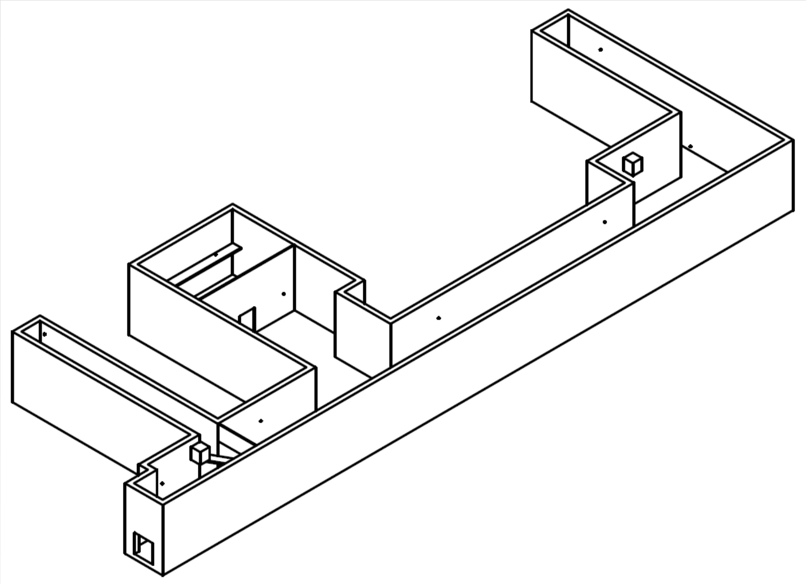


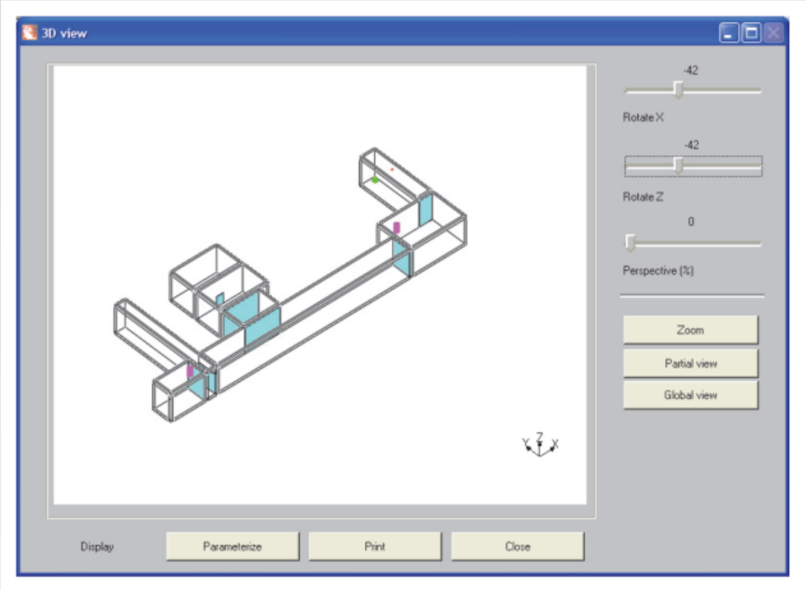


F. Lube Oil Fire in a Turbine Building

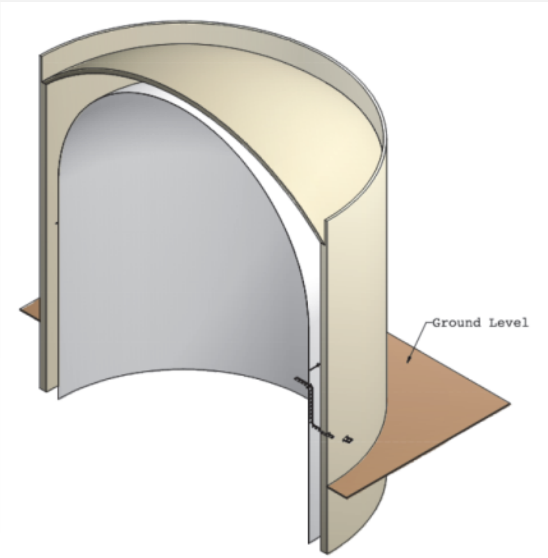


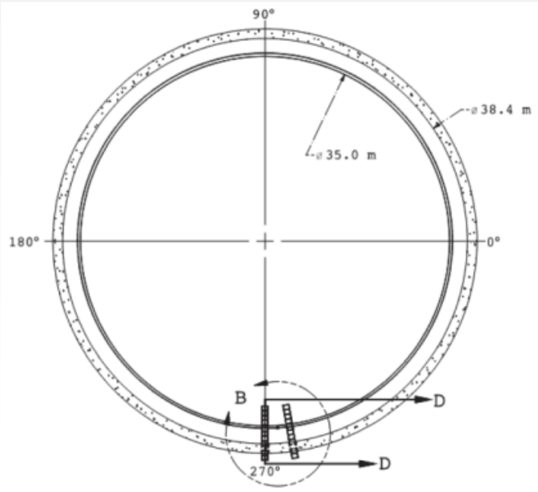
G. Transient Fire in a Multi-Compartment Corridor

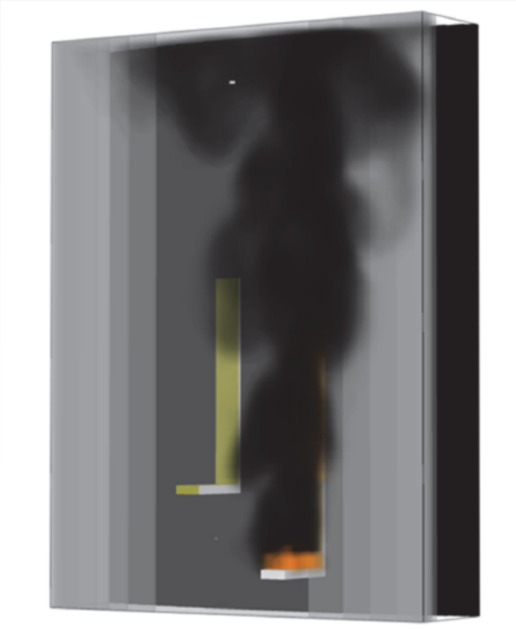




H. Cable Tray Fire in the Annulus







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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

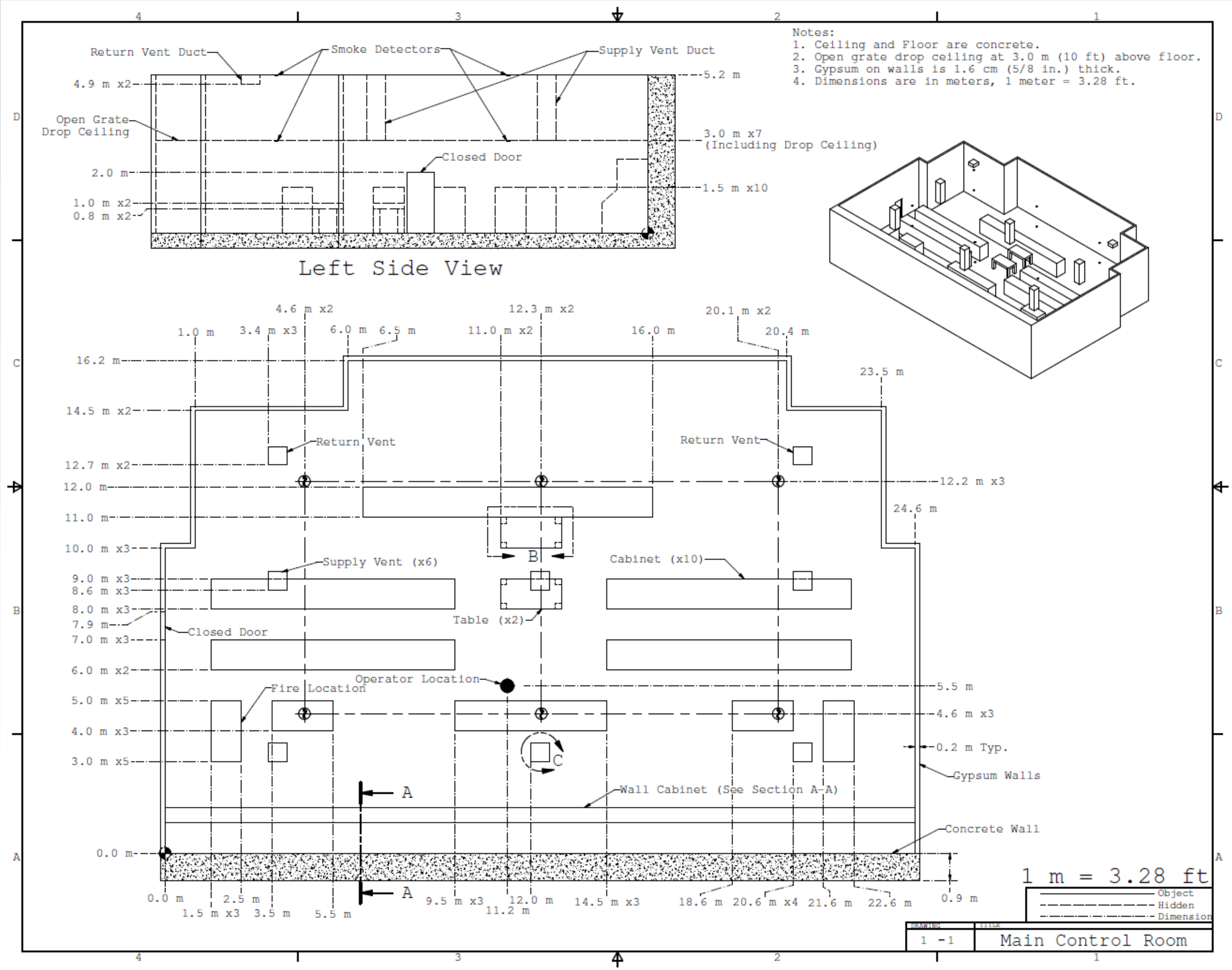
The purpose of the calculations described in this appendix is to determine the length of time that the main control room (MCR) remains habitable after the start of a fire within a low-voltage control cabinet. These calculations follow the guidance provided in NUREG/CR-6850 (EPRI 1011989), Volume 2, Chapter 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 kW/m^2. A smoke layer temperature of approximately 95 °C (200 °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[9] than 3 m^{-1}.

A.2 Description of Fire Scenario



A.2 (cont.) Description of Fire Scenario

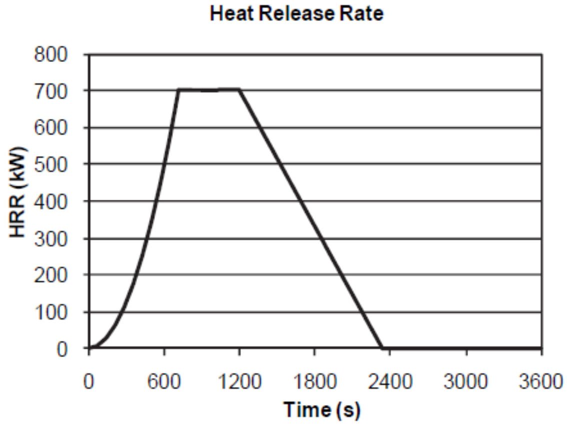


Figure A-5. Time history of the HRR used by all models in the MCR scenario.

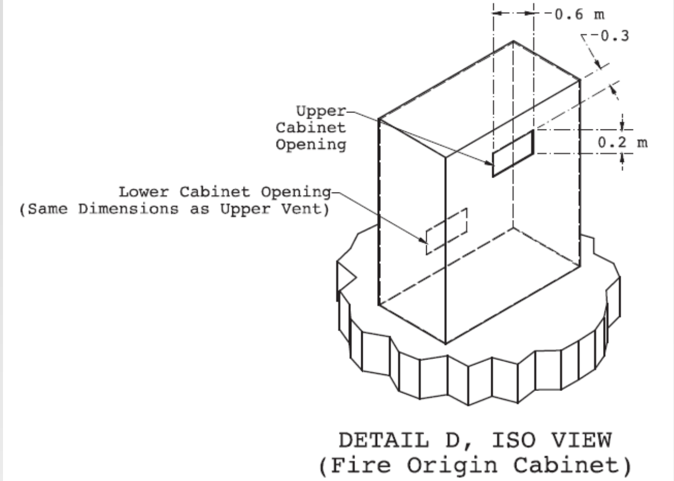


Table A-1. Data for MCR fire based on XPE/neoprene electrical cable.

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	*SFPE Handbook*, 4th ed., Table 3-4.16
CO_2 Yield	0.63 kg/kg	*SFPE Handbook*, 4th ed., Table 3-4.16
Soot Yield	0.175 kg/kg	*SFPE Handbook*, 4th ed., Table 3-4.16
CO Yield	0.082 kg/kg	*SFPE Handbook*, 4th ed., Table 3-4.16
Radiative Fraction	0.53	*SFPE Handbook*, 4th ed., Table 3-4.16
Mass Extinction Coefficient	8700 m^2/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, φ, of the Room, based on Forced Ventilation of Purge Mode	$\varphi = \frac{\dot{Q}}{\Delta H_{O_2} \dot{m}_{O_2}} = \frac{702\ \text{kW}}{13{,}100\ \text{kJ/kg} \times 3.7\ \text{kg/s}} \cong 0.014$ $\dot{m}_{O_2} = Y_{O_2}\ \rho_\infty \dot{V} = 0.23 \times 1.2\ \text{kg/m}^3 \times 13.4\ \text{m}^3/\text{s} \cong 3.7\ \text{kg/s}$	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

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.

Require Justification

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, ρ, the volume of the room, V, and the mass fraction of oxygen in the air, Y_{O_2}:

$$m_{O_2,\mathrm{tot}} = \rho V Y_{O_2} = 1.2\ \mathrm{kg/m^3} \times 1945\ \mathrm{m^3} \times 0.23 \cong 537\ \mathrm{kg} \quad \text{(A-1)}$$

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:

$$m_{O_2,\mathrm{req}} = \frac{Q}{\Delta H_{O_2}} \cong \frac{702\ \mathrm{kW} \times 60\ \mathrm{s/min} \times \left(\frac{12}{3} + 8 + \frac{19}{2}\right)\ \mathrm{min}}{13{,}100\ \mathrm{kJ/kg}} \cong 69\ \mathrm{kg} \quad \text{(A-2)}$$

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)

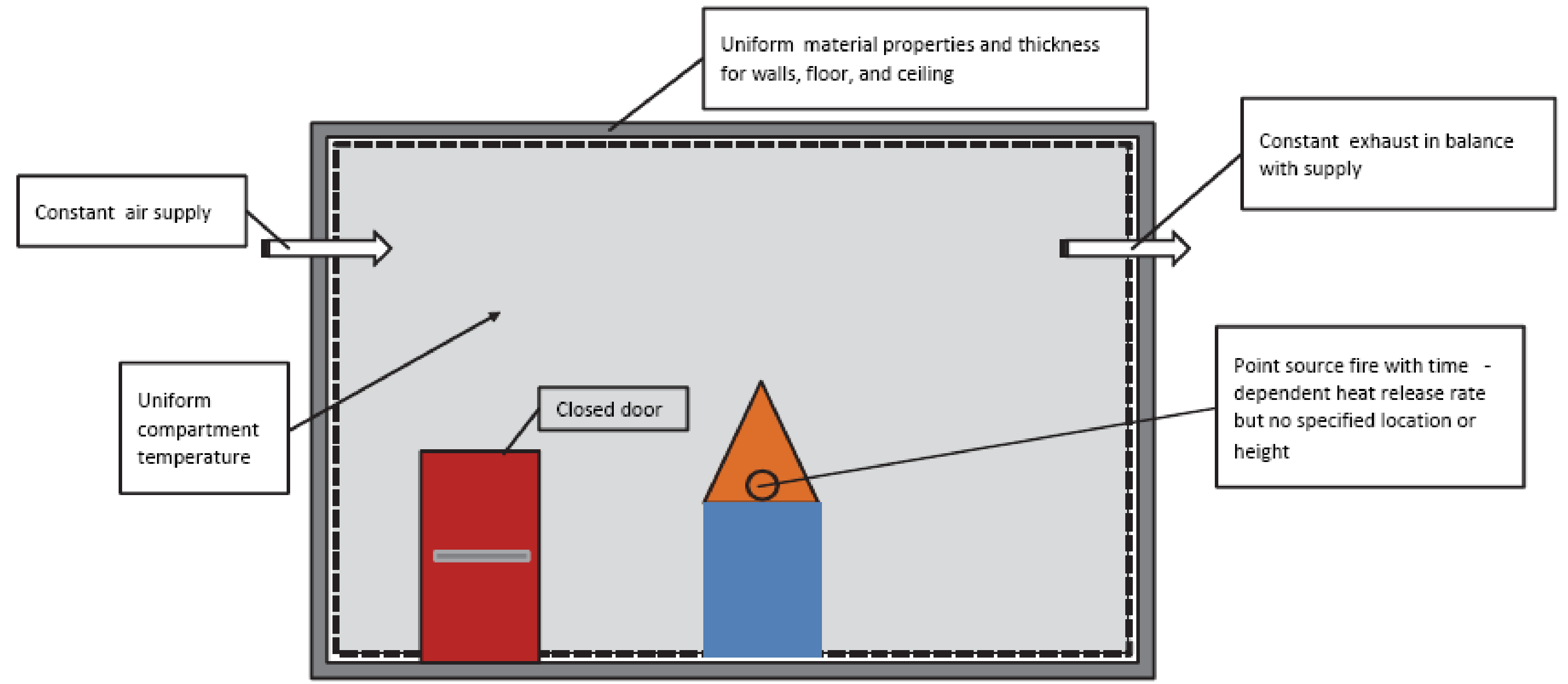
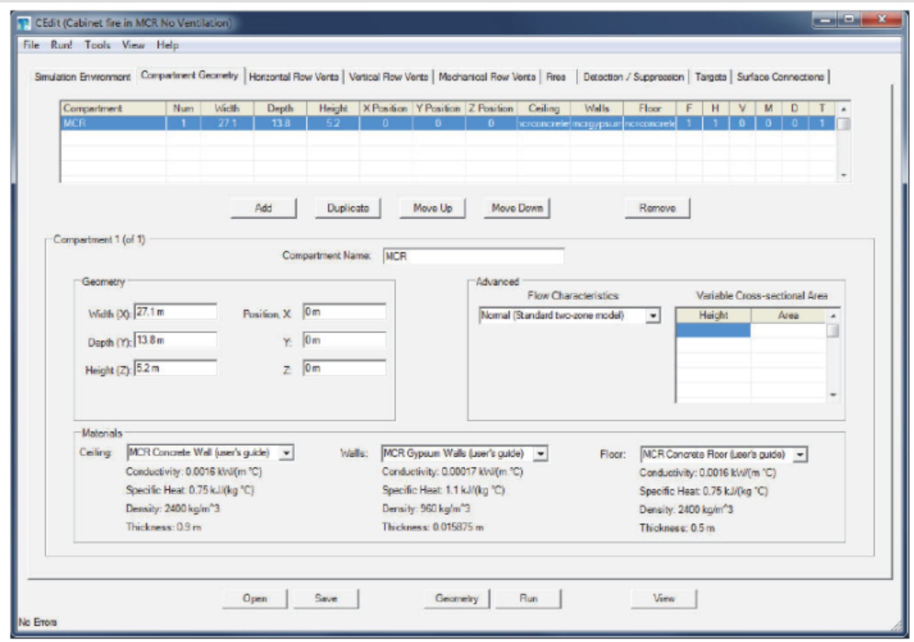
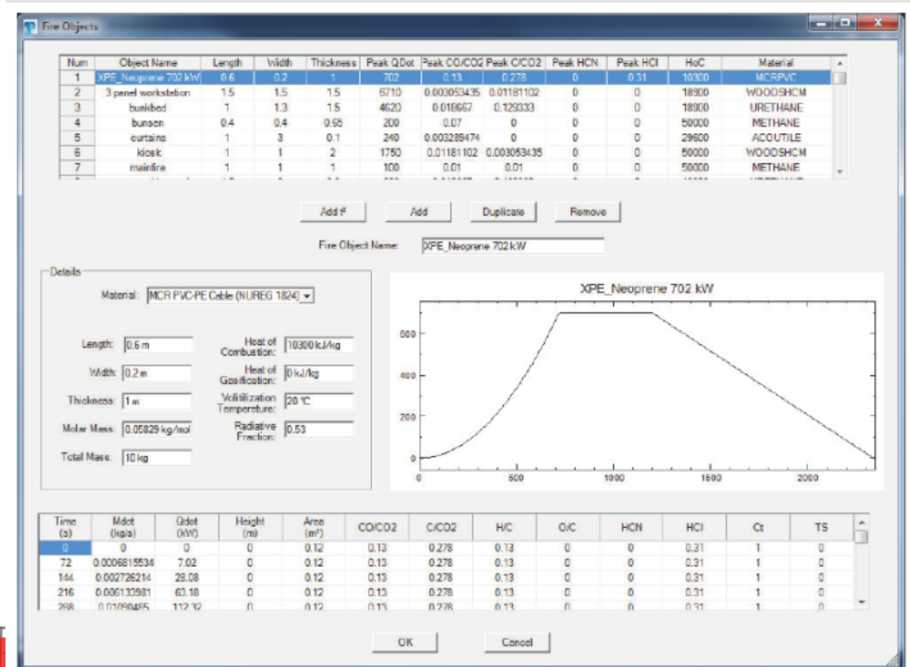


Figure A-6. Schematic diagram of the FPA calculation for the MCR smoke purge scenario.

A.4 (cont.) Estimatation 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.

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".

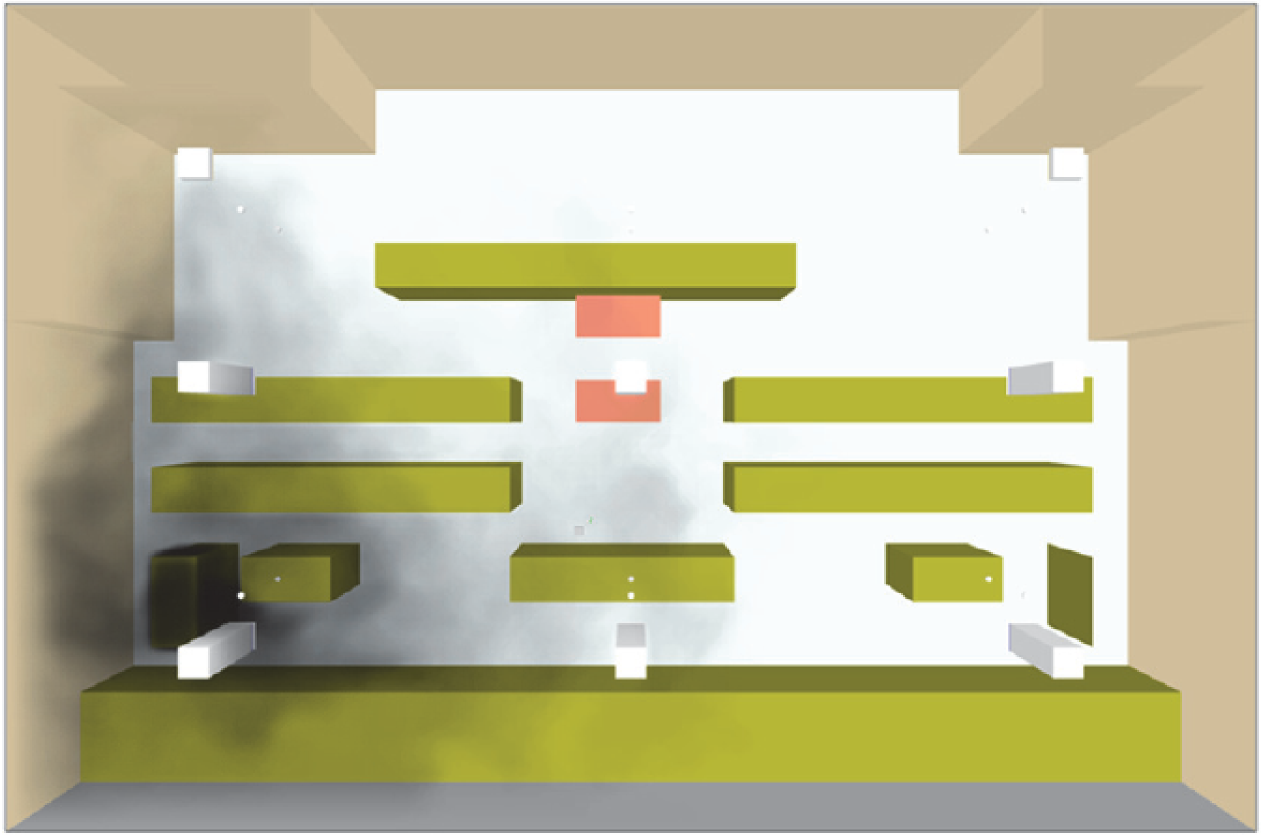


Figure A-11. FDS/Smokeview rendering of the MCR, as viewed from above.

A.5 Evaluation of Results

Table A-4. Summary of the model predictions of the MCR scenario.

Model	Bias Factor, δ	Standard Deviation, $\tilde{\sigma}_M$	Ventilation	Predicted Value	Critical Value	Probability of Exceeding
Temperature (°C), Initial Value = 20 °C						
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Heat Flux (kW/m^2)						
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
Optical Density (m^{-1})						
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.

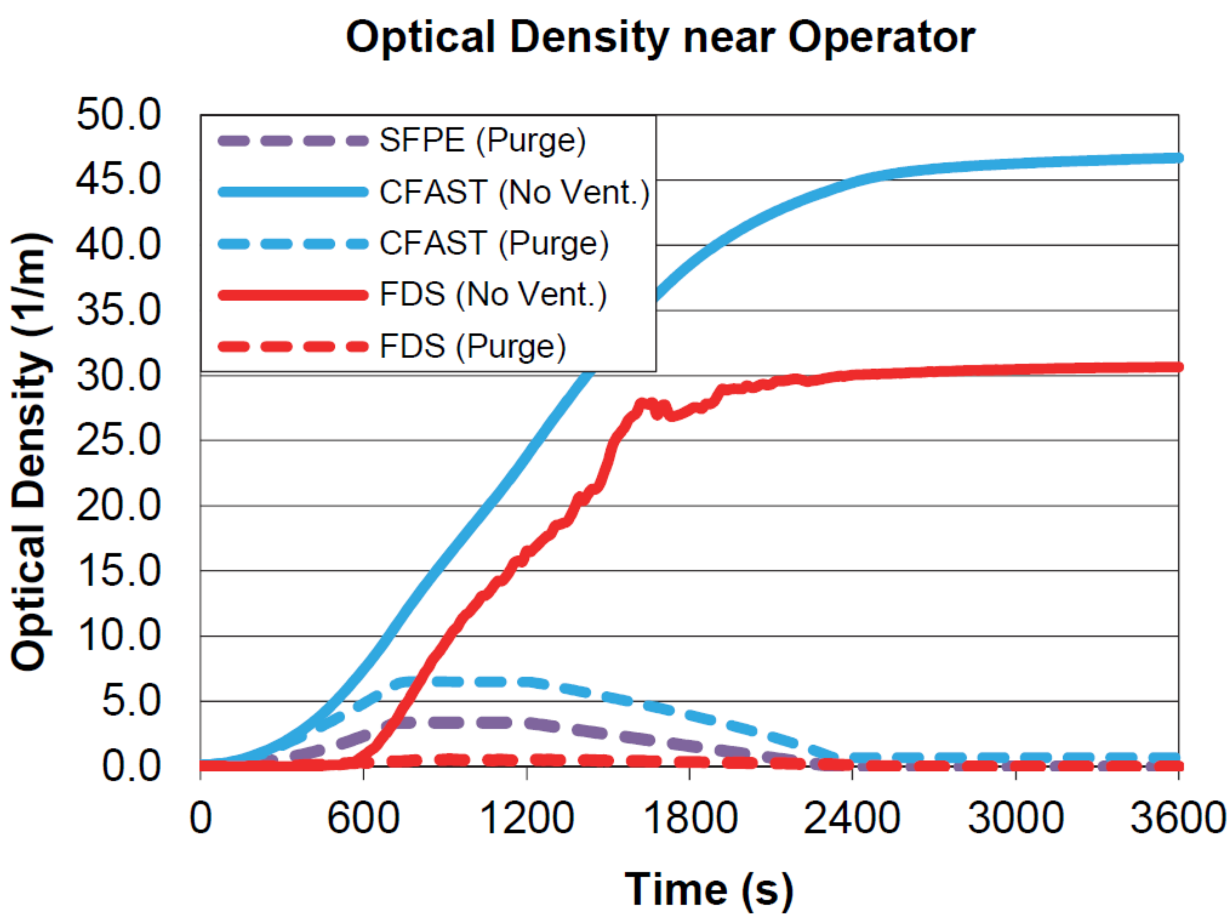

Figure A-14. Optical density predictions for the MCR scenario.

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 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

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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