TVSFPE Secretary’s Report
11/2/2023

Sign-In Sheet: Attachment 1
Meeting Minutes: Attachment 2
Reference Information: Attachment 3

2023
TVSFPE Chapter Members
& Local Members of the Chapter

Date: 11/2/2023	TOPIC: Reviewing Fire Modeling Analysis Reports	Presented by: Scott Rockwell

Member		Chapter Membership	2023 Dues	Signature
Alamri	Fahad	Student	N/A	
Albertsen	Brent	Professional Member		
Alt	Matthew	Local-Only Member		
Altman	Christopher	Student	N/A	
Baity	David	Professional Member	Paid	David Baity
Bane	Pamela	Local-Only Member		
Barrack	Sam	Professional Member	Paid	[signature]
Bartek	Dave	Member		
Beasland	William	Local-Only Member		
Beck	Eric	Professional Member	Paid	
Berkley	Bryan	Local-Only Member		
Biggs	Brian	Local-Only Member	Paid	
Begley	Jim	Fellow		
Borum	Al	Professional Member	Paid	
Boyll	David	Local-Only Member	Paid	
Branka	Matthew	Professional Member		
Brazzell	Dal	Member	Paid	
Brown	Ethan	Member	Paid	Ethan T. Brown
Brown	Harrison	Professional Member		
Buckles	Jack	Local-Only Member	Paid	
Caldwell	Andy	Local-Only Member		
Cantu	James	Student	N/A	
Capito	Nick	Local-Only Member		
Christman	Tom	Fellow	Paid	Tom Christman
Cloyd	Tonya	Member	Paid	

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Member		Chapter Membership	2023 Dues	Signature
Coleman	David	Local-Only Member	Paid	
Coleman	Jay	Local-Only Member		
Cook	Steve	Professional Member		
Copeland	Tom	Professional Member	Paid	
Cross	Jeremy	Local-Only Member	Paid	
Daniels	Kaitlyn	Student	N/A	
Dee	Tim	Local-Only Member		
Deschambeault	Rob	Professional Member	Paid	
Devinney	David	Professional Member	Paid	
Doliber	Diane	Professional Member	Paid	
Douberly	Edward	Professional Member	Paid	
Douglas	Logan	Member		
Douglas	Ryan	Local-Only Member	Paid	
Dungan	Ken	Fellow	Paid	
Durham	Justin	Local-Only Member	Paid	
Eckroth	Jim	Local-Only Member	Paid	
Edwards	Zachary	Local-Only Member		
Felch	Chris	Professional Member		
Fetzer	Jim	Local-Only Member		
Frazer	Scott	Professional Member	Paid	[signature]
Freels	Doug	Professional Member	Paid	
Gardner	Justin	Local-only Member	Paid	[signature]
Gilliam	Chris	Local-Only Member	Paid	
Gillmann	Colby	Student	N/A	
Goranson	Harvey	Professional Member	Paid	

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Member		Chapter Membership	2023 Dues	Signature
Greenwell	Jacob	Local-Only Member		
Greer	David	Professional Member	Paid	
Gump	Jack	Local-Only Member	Paid	
Hall	Kyle	Local-Only Member	Paid	
Hartford	Clifton	Member		
Higgins	Tommy	Member	Paid	
Henderson	Alan	Member		
Hogan	Scott	Professional Member	Paid	
Houff	CJ	Student	N/A	
House	David	Professional Member	Paid	
Hughes	Bradley	Professional Member		
Icove	Dave	Fellow	Paid	
Jenkins	Bobby	Local-Only Member		
Johnson	Dan	Local-Only Member	Paid	
Kasmauskas	Dominick	Professional Member	Paid	
Klima	Steve	Local-Only Member		
Kurr	Amy	Student	N/A	
Landmesser, Jr.	Jimmy	Professional Member	Paid	
Landmesser, Sr.	Jim	Professional Member	Paid	
Larson	Alan	Professional Member	Paid	
Laubach	Eric	Member	Paid	
Livesey	Hannah	Student	N/A	
Massey	Shay	Professional Member	Paid	
Masters	Mike	Local-Only Member	Paid	
McEnery	John	Local-Only Member	Paid	

$40 (cash) 2024

2023
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Member		Chapter Membership	2023 Dues	Signature	
McNeely	Brett	Local-Only Member			
Migun	Peter	Local-Only Member			
Miller	Leonard	Local-Only Member	Paid		
Nelson	Steve	Student	N/A		
Oare	Jim	Local-Only			
Overton	Monty	Professional Member	Paid		
Patterson	Eric	Member			
Phillips	Dennis	Local-Only Member			
Platfoot	Luke	Professional Member	Paid		
Platfoot	Mark	Local-Only Member	Paid		
Presnell	Joshua	Local-Only Member	Paid		
Presnell	Stephen	Professional Member	Paid		
Rippetoe	Blake	Local-Only Member	Paid		
Rockwell	Norm	Member			
Rockwell	Scott	Member	Paid		
Rogers	Kenny	Local-Only Member	Paid		
Russell	Kirk	Member			
Russell	Matt	Local-Only Member	Paid		
Sellers	J.R.	Professional Member	Paid		
Sharp	Gary	Professional Member	Paid		
Shehane	Michael	Local-Only Member	Paid		
Siem	Mark	Member	Paid		
Sinasac	Tim	Local-Only Member	Paid		
Sipes	Jeff	Professional Member	Paid		$40 Check
Smith	Patrick	Professional Member	Paid		

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Member		Chapter Membership	2023 Dues	Signature
Smith	William	Member	Paid	
Solomon	Travis	Local-Only Member		
Spellman	Matthew	Local-Only Member	Paid	
Stallions	Will	Student	N/A	
Steneck	Paul	Member		
Sterchi	John	Professional Member	Paid	
Summers	Lisa	Local-Only Member		
Tallent	John	Member		
Thornton	Patrick	Professional Member	Paid	
Till	Bernie	Fellow	Paid	
Tinsley	Andrew	Local-Only Member	Paid	[illegible]
Tomecek	Dave	Local-Only Member		
Torbett	Todd	Member		
Tyler	Eric	Member	Paid	
Tulay	Mark	Student	Paid	
VanLandigham	Sara	Member		
Vargas	Leonardo	Student	N/A	
Vuoso	Jerry	Professional Member	Paid	
Waggoner	Wayne	Local-Only Member	Paid	
Walker	Rodney	Local-Only Member		
Walmsley	Channing	Local-Only Member	Paid	[illegible] 40# Cash 2024
Walters	Glenn	Member	Paid	
Williams	Jesse	Professional Member	Paid	
Woolard	Geoff	Local-Only Member	Paid	
Temples	Spencer	spencerctemples@gmail.com		

SFPE

2023
TVSFPE Chapter Members
& Local Members of the Chapter

Levels of Membership:

A. Fellow: Fellow is the highest grade of membership in SFPE.
B. Member (MSFPE): A Member shall be a person who supports the goals and objectives of the Society. Membership starts immediately upon completing the online member application and submission of dues payment.
C. Professional (PMSFPE): A Professional Member is a graduate of an engineering curriculum of accepted standing and shall have completed not less than four years of practice indicative of growth in engineering competency and achievement, three of which shall have been in responsible charge.
D. Associate Member:
E. Affiliate:
F. Student Member: A Student Member shall be enrolled full-time in an engineering curriculum or an engineering technology curriculum and not have full-time employment.
G. Honorary Member:
H. Local-Only Member:

TVSFPE GENERAL MEMBERSHIP MEETING

Meeting Minutes
November 2nd, 2023

Meeting began with introductions at 6:02 p.m.

REPORTS

Minutes were emailed from previous meeting. Scott Frazer motioned to accept the minutes. Kyle Hall second. Motion carries.

President Tinsley presented the Treasurer's Report. No further comments.

OLD BUSINESS

- No Old Business.

NEW BUSINESS

- No New Business.

Business meeting concluded at 6:18 p.m.

Minutes submitted by: Justin Gardner

TVSFPE Chapter Meeting

November 2, 2023

Speaker – Scott Rockwell

Welcome

- Introductions
- Minutes from October 2023 Meeting

Treasurer's Report

- ORNL FCU Account balances:
  - Checking: $5,154.68
  - Savings: $8,126.56
    - Includes the money designated for burn trailer support
- Fidelity Investment Account
  - Total Value: $491,068.31
- Paypal Account
  - Total Value: $250

Old Business

- Pay your 2024 Dues!!!!

New Business

- Future Meetings
  - Any suggestions/interested topics?? Please email them to president@tvsfpe.org
- Seminar – Suggestions for 2024?
- Next Meeting is 1/4/24
  - Speaker is TBD.
  - Location: Mimi's Cafe
- Research Proposal Presentation
- Other items??

SPEAKER

Reviewing a Fire Modeling Report: Suggesting a Suspicious Attitude

(If you see pretty pictures, get more suspicious)

TVSFPE Monthly Meeting
Presenter: Scott R. Rockwell
11/2/2023

Mathematical modeling in FPE

- Uses math to quantify fire hazard (e.g., in Performance-Based design)
- part of scientific method of investigation
  - *"Do my hypotheses work?"*
- Timeline Analysis
  - Survivability, injury, etc.

- models are calculations that describe the behavior of real world physical occurrences (use math to represent simplified real word behavior)
  - Hand calculations
  - Spread sheet or other relatively simple automated numerical model programmed using MATLAB, Python, C++, Etc.
  - Zone models
  - Field models

General Limitations

- Currently validated as a fire effects models based on a specified Heat Release Rate curve
  - Can't reliably model flame spread though FDS has that function built in.
- Geometrical limitations
- Assumptions on energy spread
- Easy to fool people with pretty pictures, including yourself

- Functionality expected to increase over time, along with increased risk of erroneous results from model misuse. (e.g., old paper modeling backdraft with CFAST)

Hand Calculations / author generated spreadsheet calculations

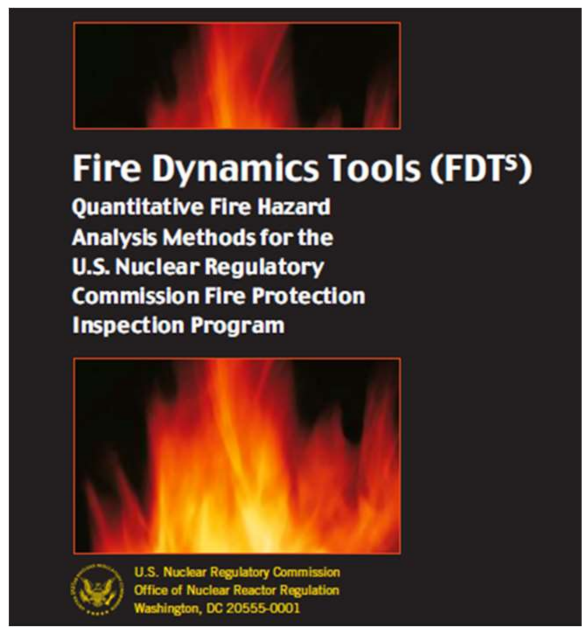
- typically algebraic equations
- Published correlations usually based on experimental data
- estimate the effects of fire phenomena
  - simple configurations
- Lots of assumptions
- not typically time-dependent.

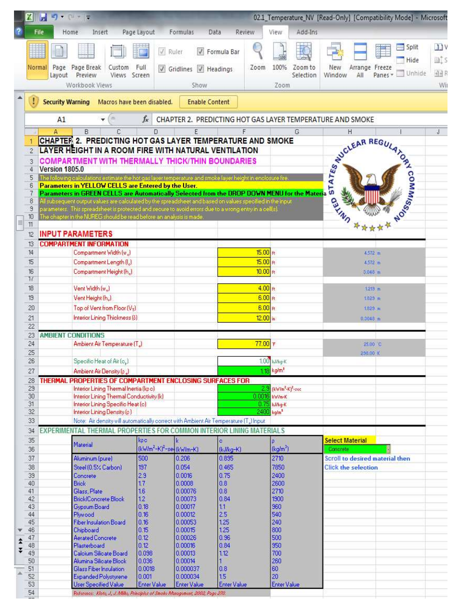
- Verification and Validation is a potential issue, calculations should be shown/verifiable in report.

Spread sheet modeling

- Automating hand calculations, adding time dependency or effect of input parameter variation
- Fire Dynamics Tools (FDTs) which was created and is still supported by the U.S. Nuclear Regulatory Commission (verified and validated).

Validation is a potential issue for custom spreadsheets, calculations should be shown/verifiable in report.





Zone Models

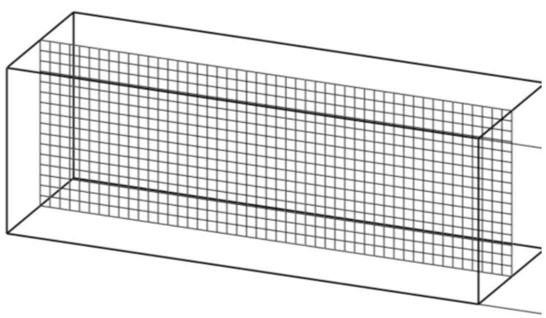
- separates the compartment into two zones
  - upper (hot) zone and lower (cool) zone
- simplifies various aspects of the enclosure fire to assist in predicting fire conditions
  - solves conservation equations (mass, species, energy) for each zone
  - The lower zone receives air (mass) from outside the compartment and loses air to the upper zone

Consolidated Model of Fire Growth And Smoke Transport (CFAST)

- multi-room zone model

Field Model

- uses computational fluid dynamics (CFD)
  - separate a compartment into thousands of cells
  - more calculation intensive
  - field models calculates the conservation equations for each cell and balanced with adjacent cells.
    - relate energy transfer and flow of fluids from cell to cell

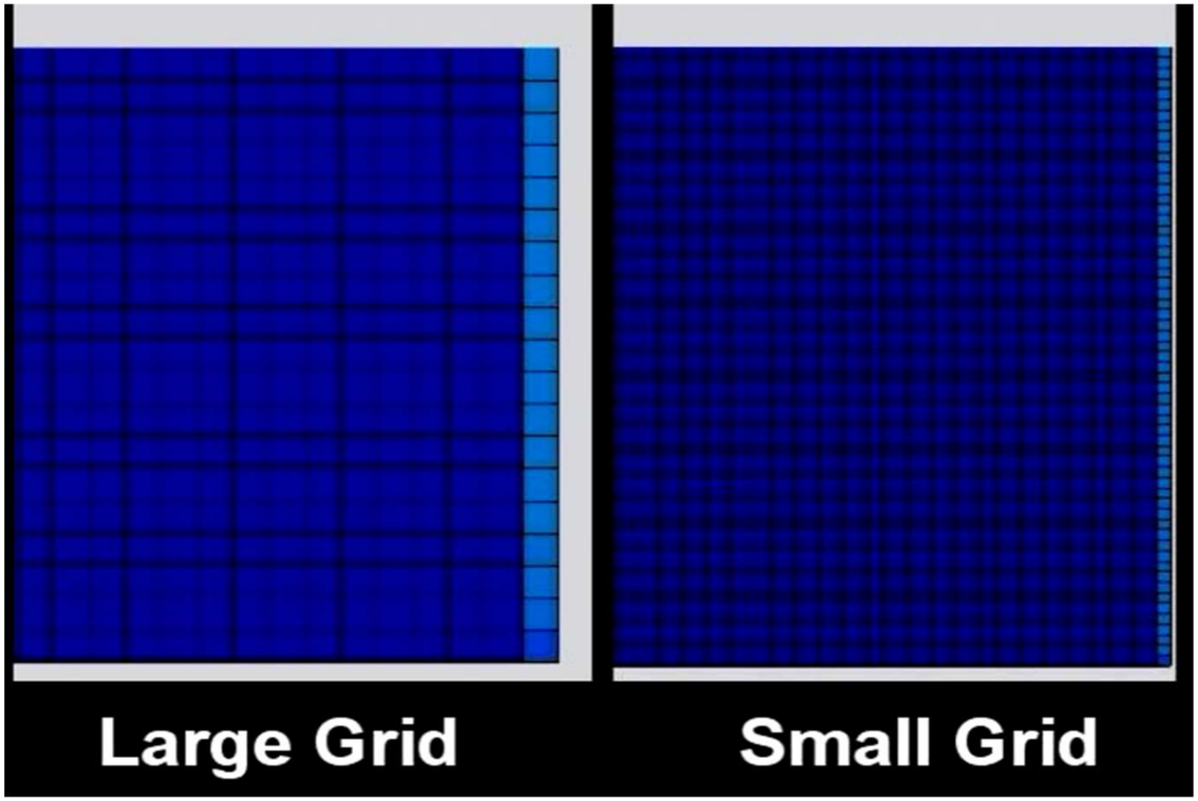


- Fire Dynamics Simulator (FDS)
  - calculates
    - temperature, pressure, species concentrations, and flow field in relation to the prescribed fire.
    - predicts activation of heat detectors and sprinklers.
- Smokeview
  - companion animation software that visualizes FDS and CFAST output.

For field models: Is a grid spacing analysis presented?

- Can use D* to get a general idea of grid size to start with.

- Example: Effect of grid spacing on temperature distribution in surface due to heat transfer into surface from a hot side.



Reviewing a Fire Modeling Report

Are the affects of simplifications/assumptions evaluated in the report?

- Is the evaluation bounding (using large and small values if applicable)?
- Are the limits of equations identified in analysis, or an explanation provided for why the equations used are appropriate.
- Are equations derived or referenced appropriately?
- Does the author explain why the approach used is appropriate as compared to other options? (This could be one sentence/paragraph).

Is the installation of the program used in the report Verified and Validated for the scenario being modeled? – Can you trust the model to answer the question being asked?

- Is data display method validated?
- If using a third party software (e.g., pyrosim), is that program validated to interpret the FDS output appropriately.

Is data from modeling available for review as part of the report record

- E.g., input files, output files, etc.

- Separate file
- Appendix of report

Do model input have uncertainty analyzed? Is a statistically adjusted conservative input parameter used in the model?

If input data is from fire testing, what is the uncertainty of the test method?

(ASTM general provides some indication of standardized test uncertainties.)

Are inputs parameters Justified? Aka is there language in the report describing what the inputs are based on (Or why inputs are conservative for the given scenario).

- SFPE handbook Cha 76 - Uncertainty

Is the Model Output Uncertainty evaluated

https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1824/index.

6.3 Summary of Validation Results

Table 6-1 summarizes the results of this validation study. As discussed in Section 6.1, the predictive capabilities of the models are assessed based on the quantitative values of relative difference between model prediction and experimental measurements.

Note that the values in Table 6-1 are based on the versions of the models listed in Section 1.3. These values may not apply to earlier versions of the models. In particular, the model accuracy metrics that were cited in NUREG-1934 (EPRI 1023259) in 2012 are based on earlier versions of the models.

In general, the CFD model FDS is the most accurate, followed by the zone models, followed by the empirical correlations. This is to be expected because CFD models are more faithful to the underlying physics, but they also require hours or days to complete calculations that can be done in less than a minute by the other models.

There are some exceptions to the general hierarchy of models. For example, FDS is of comparable accuracy to the zone models in predicting plume temperatures. This is not surprising because the zone models use well-established empirical correlations of plume temperatures, whereas FDS predicts these temperatures by solving the governing fluid flow equations. At best, FDS should predict comparable temperatures.

The zone and CFD models all over-predict smoke concentration by approximately a factor of three, possibly because the models do not account for smoke losses to the walls and ceiling.

The zone models are relatively accurate in predicting the average HGL temperature, but less accurate in predicting localized surface temperatures and heat flux.

NUREG-1824
Supplement 1

EPRI 3002002182

Verification and Validation of Selected Fire Models for Nuclear Power Plant Applications

Supplement 1

FINAL REPORT

U.S. Nuclear Regulatory Commission
Office of Nuclear Regulatory Research
Washington, D.C. 20555-0001

Electric Power Research Institute
3420 Hillview Avenue
Palo Alto, CA 94304-1338

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Is the Model Output Confidence level evaluated

- NUREG-1824 Supplement 1, Table 6.1

Table 6-1
Summary of Model Uncertainty Metrics

Output Quantity	Empirical Correlations			CFAST		MAGIC		FDS		Exp
	Corr.	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	$\tilde{\sigma}_E$
HGL Temp. Rise, Natural Ventilation	MQH	1.17	0.15	1.21	0.38	1.13	0.33	1.02	0.07	0.07
HGL Temp. Rise, Forced Ventilation	FPA	1.29	0.32	1.13	0.23	1.04	0.15	1.14	0.20	0.07
	DB	1.18	0.25							
HGL Temp. Rise, No Ventilation	Beyler	1.04	0.37	0.99	0.24	1.07	0.16	1.16	0.11	0.07
HGL Depth	ASET/ Yamana and Tanaka (YT) Smoke-Filling Correlation	-	-	1.01	0.29	1.08	0.27	1.04	0.06	0.05
Ceiling Jet Temp. Rise	Alpert	0.86	0.11	1.06	0.42	1.04	0.46	0.99	0.12	0.07
Plume Temp. Rise	Heskestad	0.80	0.33	1.09	0.29	1.03	0.19	1.12	0.21	0.07
	McCaffrey	0.90	0.31							
Oxygen Concentration	N/A			1.08	0.28	1.01	0.22	0.99	0.13	0.08
Smoke Concentration	N/A			3.42	0.68	3.71	0.66	2.63	0.60	0.19
Pressure Rise	N/A			1.37	0.63	1.32	0.20	1.00	0.23	0.23
Target Temp. Rise	Steel	1.29	0.45	1.25	0.49	1.04	0.38	0.99	0.17	0.07
Target Heat Flux	Point Source	1.39	0.50	1.04	0.59	0.85	0.66	0.97	0.26	0.11
	Solid Flame	1.17	0.44							
Surface Temp. Rise	N/A			1.02	0.22	0.93	0.28	0.98	0.12	0.07
Surface Heat Flux	N/A			0.94	0.26	0.76	0.33	0.89	0.17	0.11
Cable Failure Time	THIEF	0.90	0.11	-	-	-	-	1.10	0.16	0.12
Sprinkler Activation Time	Sprinkler	1.11	0.41	1.01	0.20	0.91	0.20	0.93	0.15	0.06
Smoke Detector Act. Time	Temp. Rise	1.07	0.58	1.77	0.39	1.44	0.38	1.22	0.34	0.34

For a given model prediction M, the "true" value of the quantity of interest is assumed to be a normally distributed random variable with a mean value of $\mu = M/\delta$ and a standard deviation of $\sigma = \tilde{\sigma}_M (M/\delta)$.

Using these values, the probability of exceeding a critical value x_c is:

$$P(x > x_c) = \frac{1}{2}\mathrm{erfc}\left(\frac{x_c - \mu}{\sigma\sqrt{2}}\right) \quad (6\text{-}4)$$

6.1.2 Limitation of the Method

The relatively simple method described above for quantifying model uncertainty is based on the assumption that the relative difference between model prediction and experimental measurement is normally distributed. For large data sets, this can be checked qualitatively by visual inspection. For example, for the data shown in Figure 6-1, the quantity $\ln(M/E)$, when presented in the form of a histogram, does appear to be normally distributed. However, in some cases the data do not appear to be normally distributed. Consider, for example, the data shown in Figure 6-3. The model uncertainty bounds (red dashed lines) do not appear to evenly straddle the data. In this case, the data from one set of experiments (UL/NIST Vents) tend to skew the distribution. It might be argued that these data be analyzed using a different assumption about the distribution. However, this would seriously complicate the presentation of the results and make it much more difficult to apply the uncertainty metrics in the way presented above.

https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1824/ir

General method

Part 14.1: General equation nomenclature and overview from NUREG-1824, Supplement 1; Sect. 6.1
Model Uncertainty Metrics

$P(x > x_c)$ – probability that model calculated value of x is greater than critical value x_c, Eq. 14.1-3

x_c – variable critical value

x – Model output parameter

M – Model Prediction value relative to critical value ($= x - x_0$ in case where the variable is a "rise" such as a temperature rise)

δ – model bias factor (found in NUREG-1824, Supplement 1; Table 6-1)

$\tilde{\sigma}_M$- models relative standard deviation (found in NUREG-1824, Supplement 1; Table 6-1)

μ – mean value of normally distributed random variable, Eq. 14.1-1

σ – standard deviation of normally distributed random variable, Eq. 14.1-2

$$\mu = \frac{M}{\delta} \quad \text{(Eq. 14.1-1)}$$

$$\sigma = \tilde{\sigma}_M \left(\frac{M}{\delta}\right) \quad \text{(Eq. 14.1-2)}$$

$$P(x > x_c) = \frac{1}{2} erfc\left(\frac{x_c - \mu}{\sigma\sqrt{2}}\right) \quad \text{(Eq. 14.1-3)}$$

Example Confidence Level Calculation

- NUREG-1824 Supplement 1, Table 6.1
- Is a 95% confidence interval calculated?

6.1.1 Example

As an example of how to use the uncertainty metrics, consider the following example. Suppose that electrical cables within a compartment are assumed to fail if their surface temperature reaches 330 °C (626 °F). Suppose also that the CFD model FDS predicts that the maximum cable temperature caused by a fire within the compartment is 300 °C (572 °F). What is the probability that the cables could fail?

Step 1: Subtract the ambient value of the cable temperature, 20 °C (68 °F), to determine the predicted temperature <u>rise</u>. Refer to this value as the *model prediction*, M:

$$M = 300\ °\mathrm{C} - 20\ °\mathrm{C} = 280\ °\mathrm{C} \quad (6\text{-}6)$$

Step 2: Refer to Table 6-1, which indicates that, on average, FDS under-predicts target temperatures with a bias factor, δ, of 0.99. Calculate the *adjusted model prediction*:

$$\mu = \frac{M}{\delta} = \frac{280\ °\mathrm{C}}{0.99} \cong 283\ °\mathrm{C} \quad (6\text{-}7)$$

Referring again to Table 6-1, calculate the standard deviation of the distribution:

$$\sigma = \tilde{\sigma}_M \left(\frac{M}{\delta}\right) = 0.17 \left(\frac{280\ °\mathrm{C}}{0.99}\right) \cong 48\ °\mathrm{C} \quad (6\text{-}8)$$

[8] Excel 2007 does not evaluate $\mathrm{erfc}(x)$ for negative values of x, even though the function is defined for all real x. In such cases, use the identity $\mathrm{erfc}(-x) = 2 - \mathrm{erfc}(x)$.

Step 3: Calculate the probability that the actual cable temperature would exceed 330°C (626°F):

$$P(T > 330\ °\mathrm{C}) = \frac{1}{2}\,\mathrm{erfc}\left(\frac{T - T_0 - \mu}{\sigma\sqrt{2}}\right) = \frac{1}{2}\,\mathrm{erfc}\left(\frac{330\ °\mathrm{C} - 20\ °\mathrm{C} - 283\ °\mathrm{C}}{48\ °\mathrm{C}\,\sqrt{2}}\right) \cong 0.40 \quad (6\text{-}9)$$

½*Erfc not evaluated

https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1824/index.html

6.1.1 Example Solution: Step by step

Switch to Word Document and excel sheet - information copied on slides for completeness

Part 14.1.1: Example Calculation from NUREG-1824, Supplement 1; Sect. 6.1.1

Pg. 6-3 – 6-4 example calculation (1/2*erfc function is not evaluated in Eq. 6-9)

$\delta = 0.99$ – FDS model bias factor for temp rise, Table 6.1

$\tilde{\sigma}_M = 0.17$- FDS models relative standard deviation for temp rise, Table 6.1

Table 6-1
Summary of Model Uncertainty Metrics

Output Quantity	Empirical Correlations			CFAST		MAGIC		FDS		Exp
	Corr.	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	$\tilde{\sigma}_E$
Target Temp. Rise	Steel	1.29	0.45	1.25	0.49	1.04	0.38	0.99	0.17	0.07

Figure 14.1.1-1: Selected data from NUREG-1824, Supplement 1; Table 6-1

M=300C-20C = 280C : Model Prediction of temperature rise (Eq. 14.1.1-1)

$$\mu = \frac{M}{\delta} = \frac{280C}{0.99} = 282.8C \cong 283C \quad \text{(Eq. 14.1.1-2)}$$

$$\sigma = 0.17\left(\frac{280C}{0.99}\right) = 48.08C \cong 48C \quad \text{(Eq. 14.1.1-3)}$$

$$x_c = 330C - 20C = 310C \quad \text{(Eq. 14.1.1-4)}$$

$$P(x > x_c) = \frac{1}{2} erfc\left(\frac{310C - 283C}{48C\sqrt{2}}\right) = 0.2869 \cong 0.29 \quad \text{(Eq. 14.1.1-5)}$$

Note, example solution in NUREG-1824, Supplement 1; Sect. 6.1.1, Eq. 6-9 has error where "½*erfc" is not evaluated. Error in example confirmed with Kevin McGrattan over email. Excel solutions showing the correct calculation (row 6) and the solution with error matching NUREG-1824, Supplement 1; Sect. 6.1.1, Eq. 6-9 (row 8) shown below.

6	=1/2*ERFC((310-283)/(48*SQRT(2)))		6	0.286887702
7			7	
8	=((310-283)/(48*SQRT(2)))		8	0.397747564

Figure 14.1.1-1: Excel solutions of error function

Example 95% Confidence Level Calculation

- Is a 95% confidence interval calculated?
- P(x>x_c) <0.05

Part 14.2: Calculating 95% conf level based on NUREG-1824, Supplement 1; Sect. 6.1 method

SFPE *Engineering Guide to Performance-Based Fire Protection*, Sect. 10.5.5.1-3, recommends 95% confidence level on model input and output for analysis purposes.

95% confidence level calculation

$$P(x > x_c)_{95\%\ Conf} = 0.05 = \frac{1}{2} erfc\left(\frac{x_c - \mu}{\sigma\sqrt{2}}\right) \quad \text{(Eq. 14.2-1)}$$

$$\mu = \frac{M}{\delta} \quad \text{(Eq. 14.2-2 = Eq. 14.1-1)}$$

$$\sigma = \tilde{\sigma}_M \left(\frac{M}{\delta}\right) \quad \text{(Eq. 14.2-3 = Eq. 14.1-2)}$$

Set the probability that $P(x > x_c)$ is great than 1.00-percent confidence level/100:

$$P(x > x_c)_{95\%\ Conf} = 1.00 - \frac{95}{100} = 0.05 = \frac{1}{2} erfc\left(\frac{x_c - \frac{M}{\delta}}{\tilde{\sigma}_M\left(\frac{M}{\delta}\right)\sqrt{2}}\right) \quad \text{(Eq. 14.2-4)}$$

This can then be solved for "M" iteratively using something like a manual "guess and check" method or a numerical method such as Excel "Goal Seek"

https://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr1824/index.html

95% Conf Level Example Solution: Step by step

Part 14.2.1 Example 95% Confidence level calculation based on NUREG-1824, Supplement 1; Sect. 6.1 *Model Uncertainty Metrics*:

Flashover: 20kW/m2 to floor using a in model heat flux sensor on the floor

CFAST Target heat flux:

$\delta_{CFAST,Target\ heat\ flux} = 1.04$ – CFAST model bias factor for Target heat flux, Table 6.1

$\tilde{\sigma}_{M,CFAST,Target\ heat\ flux} = 0.59$ CFAST models relative standard deviation for Target heat flux, Table 6.1

Table 6-1
Summary of Model Uncertainty Metrics

Output Quantity	Empirical Correlations			CFAST		MAGIC		FDS		Exp
	Corr.	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	$\tilde{\sigma}_E$
Target Heat Flux	Point Source	1.39	0.50	1.04	0.59	0.85	0.66	0.97	0.26	0.11
	Solid Flame	1.17	0.44							

Figure 14.2.1-1: Selected data from NUREG-1824, Supplement 1; Table 6-1

$$P(x > x_c)_{95\%\ Conf} = P(\dot{q}_M > \dot{q}_{c,FO})_{95\%\ Conf} = \frac{1}{2} erfc\left(\frac{x_c - \frac{M}{\delta}}{\tilde{\sigma}_M\left(\frac{M}{\delta}\right)\sqrt{2}}\right) = 0.05 \quad \text{(Eq. 14.2.1-1)}$$

$$x_{c,FO} = 20\,\frac{kW}{m^2} \quad \text{(Eq. 14.2.1-2)}$$

M = x = $\dot{q}_M$ (heat flux rise in the model, starts at zero; therefore, no subtraction as in earlier example:

$$0.05 = \frac{1}{2} erfc\left(\frac{x_{c,FO} - \frac{q_M}{\delta_{CFAST,Target\ heat\ flux}}}{\tilde{\sigma}_{M,CFAST,Target\ heat\ flux}\left(\frac{q_M}{\delta_{CFAST,Target\ heat\ flux}}\right)\sqrt{2}}\right) \quad \text{(Eq. 14.2.1-3)}$$

$$0.05 = (1/2)\, erfc\left(\frac{20\frac{kW}{m^2} - \frac{\dot{q}_M}{1.04}}{0.59\left(\frac{\dot{q}_M}{1.04}\right)\sqrt{2}}\right)$$ → solve iteratively for $\dot{q}_M$ (Eq. 14.2.1-4)

https://www.nrc.gov/docs/ML1630/ML16309A011.pdf

Part 14.1: General equation nomenclature and overview from NUREG-1824, Supplement 1; Sect. 6.1 *Model Uncertainty Metrics*

$P(x > x_c)$ – probability that model calculated value of x is greater than critical value x_c, Eq. 14.1-3

x_c – variable critical value

x – Model output parameter

M – Model Prediction value relative to critical value ($= x - x_0$ in case where the variable is a "rise" such as a temperature rise)

δ – model bias factor (found in NUREG-1824, Supplement 1; Table 6-1)

$\tilde{\sigma}_M$- models relative standard deviation (found in NUREG-1824, Supplement 1; Table 6-1)

μ – mean value of normally distributed random variable, Eq. 14.1-1

σ – standard deviation of normally distributed random variable, Eq. 14.1-2

$$\mu = \frac{M}{\delta} \qquad \text{(Eq. 14.1-1)}$$

$$\sigma = \tilde{\sigma}_M \left(\frac{M}{\delta}\right) \qquad \text{(Eq. 14.1-2)}$$

$$P(x > x_c) = \frac{1}{2} erfc\left(\frac{x_c - \mu}{\sigma\sqrt{2}}\right) \qquad \text{(Eq. 14.1-3)}$$

Part 14.1.1: Example Calculation from NUREG-1824, Supplement 1; Sect. 6.1.1

Pg. 6-3 – 6-4 example calculation (1/2*erfc function is not evaluated in Eq. 6-9)

$\delta = 0.99$ – FDS model bias factor for temp rise, Table 6.1

$\tilde{\sigma}_M = 0.17$- FDS models relative standard deviation for temp rise, Table 6.1

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	Corr.	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	δ	$\tilde{\sigma}_M$	$\tilde{\sigma}_E$
Target Temp. Rise	Steel	1.29	0.45	1.25	0.49	1.04	0.38	0.99	0.17	0.07

Figure 14.1.1-1: Selected data from NUREG-1824, Supplement 1; Table 6-1

M=300C-20C = 280C : Model Prediction of temperature rise (Eq. 14.1.1-1)

$$\mu = \frac{M}{\delta} = \frac{280}{0.99} = 282.8C \cong 283C \quad \text{(Eq. 14.1.1-2)}$$

$$\sigma = 0.17\left(\frac{280C}{0.99}\right) = 48.08C \cong 48C \quad \text{(Eq. 14.1.1-3)}$$

$$x_c = 330C - 20C = 310C \quad \text{(Eq. 14.1.1-4)}$$

$$P(x > x_c) = \frac{1}{2}erfc\left(\frac{310C - 283}{48C\sqrt{2}}\right) = 0.2869 \cong 0.29 \quad \text{(Eq. 14.1.1-5)}$$

Note, example solution in NUREG-1824, Supplement 1; Sect. 6.1.1, Eq. 6-9 has error where "½*erfc" is not evaluated. Error in example confirmed with Kevin McGrattan over email. Excel solutions showing the correct calculation (row 6) and the solution with error matching NUREG-1824, Supplement 1; Sect. 6.1.1, Eq. 6-9 (row 8) shown below.

6	0.286887702	6	=1/2*ERFC((310-283)/(48*SQRT(2)))
7		7	
8	0.397747564	8	=((310-283)/(48*SQRT(2)))

Figure 14.1.1-1: Excel solutions of error function

Part 14.2: Calculating 95% conf level based on NUREG-1824, Supplement 1; Sect. 6.1 method

SFPE *Engineering Guide to Performance-Based Fire Protection*, Sect. 10.5.5.1-3, recommends 95% confidence level on model input and output for analysis purposes.

95% confidence level calculation

$$P(x > x_c)_{95\%\,Conf} = 0.05 = \frac{1}{2}erfc\left(\frac{x_c - \mu}{\sigma\sqrt{2}}\right) \quad \text{(Eq. 14.2-1)}$$

$$\mu = \frac{M}{\delta} \quad \text{(Eq. 14.2-2 = Eq. 14.1-1)}$$

$$\sigma = \tilde{\sigma}_M\left(\frac{M}{\delta}\right) \quad \text{(Eq. 14.2-3 = Eq. 14.1-2)}$$

Set the probability that $P(x > x_c)$ is great than 1.00-percent confidence level/100:

$$P(x > x_c)_{95\%\,Conf} = 1.00 - \frac{95}{100} = 0.05 = \frac{1}{2}erfc\left(\frac{x_c - \frac{M}{\delta}}{\tilde{\sigma}_M\left(\frac{M}{\delta}\right)\sqrt{2}}\right) \quad \text{(Eq. 14.2-4)}$$

This can then be solved for "M" iteratively using something like a manual "guess and check" method or a numerical method such as Excel "Goal Seek"

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	Solid Flame	1.17	0.44							

Figure 14.2.1-1: Selected data from NUREG-1824, Supplement 1; Table 6-1

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$$0.05 = \left(\frac{1}{2}\right) erfc\left(\frac{20\frac{kW}{m^2} - \frac{\dot{q}_M}{1.04}}{0.59\left(\frac{\dot{q}_M}{1.04}\right)\sqrt{2}}\right) \rightarrow \text{solve iteratively for } \dot{q}_M \qquad \text{(Eq. 14.2.1-4)}$$