REVIEW OF COMMENT RESOLUTION FOR DRAFT NUREG-2178 V2 (11-18-2019)

Introduction

In August and September 2019, Center for Nuclear Waste Regulatory Analyses (CNWRA®) staff completed a detailed review of draft NUREG-2178, Volume 2, "Refining and Characterizing Heat Release Rates from Electrical Enclosures during Fire, Vol. 2: Fire modeling guidance for electrical cabinets, electric motors, indoor dry transformers, and the main control board" dated June 2019 (hereafter referred to as "draft NUREG-2178, Vol. 2") for the Office of Nuclear Reactor Regulation (NRR) of the U.S. Nuclear Regulatory Commission (NRC). Two types of comments resulted from this review. The first type involved substantive and technical comments, while the second set of comments were editorial in nature. In total, 170 comments were submitted to NRR (99 substantive and 71 editorial). Comment resolutions from the public comment period were received October 21, 2019. The results of CNWRA's review of the resolutions for the 170 comments that were submitted are summarized below.

Initial Review

An initial review was performed of the resolution for all comments based on the response in the "Comment Disposition/Resolution" column of the Review/Comment Documentation document ["Comment Resolution - NUREG-2178 Vol 2 (comments resolved).docx"] and, if applicable, the revised wording in the updated NUREG-2178, Vol. 2 report in which the comments were addressed ["EPRI 3002016052 NUREG 2178 Vol 2 (comments resolved).docx" dated October 2019]. The comments were grouped in four categories:

- Green Category: Typically, comments in this category were accepted and changes were made to the NUREG to address the comment.
- Yellow Category: Comments in this category were either accepted or not accepted, but it was not clear from the initial review whether the resolution was satisfactory.
- Red Category: Typically, comments in this category were not accepted and a more detailed review was conducted to confirm that the resolution was satisfactory.

Before proceeding with the detailed review of the disposition of comments in the red category, a final check was performed to determine whether any comments in the yellow category should be elevated to red. The final count of comments assigned to the green, yellow, and red categories are 126, 34, and 10, respectively. Of the 10 comments in the red category, 3 were initially in the yellow category and subsequently upgraded to red (CNWRA comments 18, 52 and 97).

Appendix A lists the complete set of comments. For each comment, the category is identified by highlighting its designation in the appropriate color. Comments upgraded from yellow to red are identified with an asterisk.

Additional Review and Discussion of Comments in the Red Category

The 10 comments in the red category are summarized in Table 1. The disposition/resolution of the comments in the red category are reprinted in Table 2.

Table 1. Summary of CNWRA comments in the red category.

Comment No.	Place in Draft	Comment Summary
CNWRA-5	*p. 2-2, line 28*	Questions the use of a value of 0.3 for the radiative fraction and points out that values of 0.37-0.63 for TP cables, and 0.35-0.63 for TS cables are reported in the SFPE Handbook.
CNWRA-18*	*p. 2-18, lines 16-20*	Suggests using the damage and ignition thresholds for different types of Kerite cable from the 2018 Fire Protection Significance Determination Process (IMC 0609 Appendix F).
CNWRA-19	*p. 2-28, lines 10-15*	Questions why, based on the grid sensitivity study presented earlier, a 20-30% correction was not applied to the radiant heat fluxes calculated in FDS with the medium-size grid.
CNWRA-52*	*p. 5-27, line 13*	Questions whether reference is made to the right figure (should be Figure 5-19 instead of 5-20).
CNWRA-63	*p. 6-6, Figure 6-3*	Suggests adding some discussion of two possible reasons why experimental plume temperatures for wall fires are lower than those calculated with the image method and the new method proposed in the NUREG (radiant fraction too low, image method assumes adiabatic wall).
CNWRA-64	*p. 6-7, Figure 6-4*	Same as CNWRA-63 but for corner fires.
CNWRA-95	*p. B-1, Table B-1*	Makes the observation that for 2 of the 16 cases, the OBs_Fac for default fuel loading is smaller than for low fuel loading and that for all other cases it is larger.
CNWRA-96	*p. B-2, Table B-2*	
CNWRA-97*	*p. D-2, line 7*	Vent ~0.3 m above bottom of Enclosure A is missing in Figure D-1.
Editorial	*p. 9-4, line 3*	In the summary of the new fire location factors, it is suggested stating that the new fire location factors provide a significant reduction in the bias and model uncertainty compared to the factors recommended in NUREG/CR-6850, Vol. 2 and the IMC 0609 Appendix F.

Table 2. Disposition/resolution of CNWRA comments in the red category.

Comment No.	Comment Disposition/Resolution
CNWRA-5	It should be noted that values from App A of the SFPE handbook are primarily from small scale fire tests that may not be larger enough to be fully turbulent as we would expect for the cabinet fires that pose a significant hazard to radiant targets. The soot yields and radiant fraction may not scale. Some of the high values reported seem inconsistent with current knowledge of extinction limits. A radiant fraction of 60 % would imply a flame temperature of ~1000 K. Methane at its LFL needs ~1200 K to sustain a flame.
CNWRA-18*	The guidance is for threshold values based on temperature. This work is primarily focused on time dependent exposures using the heat soak method for which no kerite equivalent data to the 6850 tables of flux vs damage time exist. Given that the recommendation to use TP as a surrogate is applicable.
CNWRA-19	No. The increase in flux to the medium is mostly compensated for by the bias shown in the simulations of the NIST tests. Combined with the conservative bias shown in the heat soak method, there is no need to add on additional conservativism. Added a note on the heat soak conservatism.
CNWRA-52*	No, Figure 5-20 is correct.
CNWRA-63 CNWRA-64	When comparing the experimental results to the Heskestad equation, the NIST report assumed a radiant fraction of 0.25 for use with the natural gas burners. This is similar to the assumed value of 0.3 used in the comparison presented in Figures 6-3 and 6-4. Additionally, the radiant fraction values associated with natural gas are usually less than 0.3. The original analysis documented in the referenced EPRI report considered sensitivity to wall surfaces. The results were found to not be sensitive to wall type (including the ‘inert’ type). See 3.1.4 in the referenced EPRI report. No changes made.
CNWRA-95 CNWRA-96	Obs_fac is not the ZOI. With this table, the ZOI for a cabinet is given by the ZOI computed using the solid flame model times the appropriate Obs_fac. The Solid flame ZOIs for the default fuel loads are larger than the solid flame ZOIs for the low and very low fuel loads. The actual ZOIs after multiplying by obs_fac are still larger for default than low.
CNWRA-97*	NRC to revise figure for final pub.
Editorial p. 9-4, line 3	The basis for the traditional fire location factor values does not originate in NUREG/CR-6850 or the NRC SDP and are generic values used across fire protection. No changes made.

Additional discussion of the disposition/resolutions and proposed follow-up are provided below.

CNWRA-5 (p. 2-2, line 28 in draft for public comment)

Discussion: Yang et al. reported that the radiative fraction of pool fires with a diameter between 0.1 m and 1 m is relatively constant and independent of physical size [1]. Other pool fire studies indicate that the radiative fraction of hydrocarbon fuels (slightly) increase with diameter [2-3]. Consequently, the argument that the SFPE handbook data were obtained in small-scale tests (~0.1 m diameter) and that the reported radiative fractions are therefore not representative of larger turbulent cabinet fires (~1 m diameter) does not seem to hold.

The response correctly points out that there is a limit to the flame temperature, below which combustion is not sustained. This is discussed in a paper by Quintiere and Rangwala [4], in which a critical flame temperature of 1300°C is used. However, cable jacket and insulation materials generally produce diffusion flames in which soot radiation accounts for most of the radiative heat losses. It is possible that in such sooty flames with high radiative losses, the gas phase temperature in the reaction zone remains high enough to sustain combustion.

Quintiere et al. confirmed the validity of Tewarson's approach used to obtain the radiative fraction data reported in the SFPE handbook [5]. However, this study used a similar small-scale calorimeter and therefore did not provide additional insight to determine up to what extent the data can be scaled up. Unfortunately there are no systematic large-scale studies that can be used to make this determination for electrical cable fires.

To get a feel for the radiative fraction of cable fires we estimated the convective heat release rate for a cable tray test that was conducted in the Fire Technology Department at SwRI [6]. The test involved a vertical stack of three horizontal cable trays partially filled with XLPE/PVC cable. The test was performed according to the procedure developed reported in NUREG/CR-7010, Vol. 1. The convective heat release rate was estimated based on the mass flow rate and gas temperature measured in the exhaust duct of the oxygen consumption calorimeter. The resulting estimates of the convective and radiative fractions of the heat release rate were 0.66 and 0.34, respectively. The latter is below the range of 0.37-0.63 for PE/PVC cable reported in the SFPE handbook[1], which indicates that the radiative fractions for electrical cables in the SFPE handbook are likely to be too high.

Follow-up: Although a radiative fraction of 0.3 for electrical cabinet fires appears to be too low, it is not an unreasonable generic value for the purpose of the calculations that are reported in the NUREG. Recognizing that more targets are damaged or ignited due to convective heating in the plume than due to radiative heating, using a radiative fraction of 0.3 instead of a higher value is conservative in the sense that it increases the convective fraction and therefore enlarges the vertical ZOI at the expense of narrowing the horizontal ZOI. Nevertheless, the questionable SFPE handbook values for the radiative fraction (and soot yield) are problematic and we recommend that the Office of Regulatory Research consider conducting a study to address the issue.

CNWRA-18 (p. 2-18, lines 16-20 in draft for public comment)*

Discussion: During the development of the 2018 edition of IMC 0609 Appendix F (also known as the Fire Protection Significance Determination Process), a review of existing data was conducted to determine which damage and ignition criteria to assign to the different varieties of Kerite cable. Based on the review it was decided to assume TP damage criteria for Kerite-FR cable and TS damage criteria for Kerite FR-II, FR-III, and HT cable. Furthermore, it was decided to assume TS ignition criteria for all Kerite cable varieties. The basis for this guidance is provided on page 65 of the 2018 edition of IMC 0308 Attachment 3 Appendix F. The pertinent section of the IMC, edited for clarity, is copied below:

"Additional guidance for the identification of targets and their ignition and damage criteria is provided in Attachment 4 to Appendix F. The bases for the damage and ignition thresholds in this Appendix are as follows:

…

b. Kerite Cable Targets:

1. FAQ 08-0053, Revision 1 recommends a damage threshold of 247°C (477°F) for Kerite-FR cable targets. Consequently, assuming the TP damage thresholds for Kerite-FR cable targets is conservative.
2. [FAQ 08-0053, Revision 1] further recommends using damage thresholds from NUREG/CR-7102 for Kerite FR-II, FR-III, and HT

[1] There are no data for XLPE/PVC cable in the SFPE handbook and the radiative fraction of PE/PVC is probably comparable but lower.

cable targets. [Consequently, assuming] TS damage thresholds for Kerite FR-II, FR-III, and HT cable targets is also conservative, because the lowest failure temperature reported in Table 8-3 of NUREG/CR-7102 for the Penlight tests performed on these Kerite cable varieties is 367°C (693°F).

3. The TS ignition thresholds are assumed for Kerite cable based on the fact that all varieties are IEEE 383 qualified."

According to Table 8.1 in NUREG/CR-7102, the lowest Penlight shroud temperature at which significant degradation of Kerite-FR cable was observed is 380°C. Based on Table 5.1 in the NUREG, this temperature corresponds a radiant heat flux of 8.4 kW/m², which is well above the radiant heating criterion for TP cable but below the criterion for TS cable in Appendix H of NUREG/CR-6850, Vol. 2. According to Table 8.3, most of the Penlight tests required a shroud temperature of 425°C or higher to fail the Kerite FR-II, FR-III, and HT cable specimens. The exception is Test K3, in which a Kerite FR-II cable specimen failed at a shroud temperature of 405°C. However, the failure occurred after more than one hour of exposure. Based on Table 5.1 in the NUREG, this temperature corresponds a radiant heat flux of 11 kW/m², which is equal to the radiant heating criterion for TS cable in Appendix H of NUREG/CR-6850, Vol. 2.

Follow-up: Based on the discussion above, we recommend replacing the last two sentences at the end of the paragraph below the two bullet items at the top of page 2-18 (Starts with "Since the guidance for Kerite-FR cables in …") with the following: "Based on the test results in NUREG/CR-7102 and guidance in FAQ 08-0053 Revision 1, TP damage criteria can be assumed for Kerite-FR cable and TS damage criteria can be assumed for Kerite FR-II, FR-III, and HT cable. Furthermore, TS ignition criteria can be assumed for all Kerite cable types because all Kerite varieties are IEEE 383 qualified."

CNWRA-19 (p. 2-28, lines 10-15 in draft for public comment)

Discussion: Under-predicting the heat flux by 20-30% does not appear to be "mostly compensated for" by the 10% bias shown in the simulations of the NIST tests. It is not clear from the discussion whether the conservative bias of the heat soak method can make up for the remaining 10-20%. However, the discussion in section A.5 seems to show that it probably can.

Follow-up: We suggest expanding the discussion in section 2.3.3.3 to better show that the bias in the FDS heat flux calculations combined with the bias in the heat soak method indeed compensates for the error in the heat flux predictions due to the use of the medium resolution grid. More specifically, an estimate of the bias in the heat flux method should be provided and reference should be made to section A.5.

CNWRA-52 (p. 5-27, line 13 in draft for public comment)*

Discussion: Figure 5-19 introduces all factors that are used to calculate the heat release rate according to Equation 5-2, except n_c. Figure 5-20 illustrates how the frequency distribution of n_c was determined. For these reasons we thought that the intent here was to reference Figure 5-19. Following additional review we also determined that the reference to Figure 5-19 on p. 5-26, line 41 should probably be a reference to Figure 5-20.

Follow-up: Check whether references to Figures 5-19 and 5-20 on pages 5-26 and 5-27, respectively are correct.

CNWRA-63 and CNWRA-64 (Figures 6-3 and 6-4 in draft for public comment)

Discussion: The assumed value for the radiative fraction of 0.3 used in the comparisons presented in Figures 6-3 and 6-4 is indeed high for methane. The results of the sensitivity analysis in the EPRI report address the second part of the comment.

Follow-up: No further action is needed.

CNWRA-97 (Figure D-1 in draft for public comment)*

This comment has been addressed. Other than updating the figure, no further action is needed.

Editorial (p. 9-4, line 3 in draft for public comment)

Discussion: The basis for the traditional fire location factor values indeed does not originate in NUREG/CR-6850 or the NRC FP SDP. However, the new fire location factor guidance in the NUREG will eventually replace the guidance in NUREG/CR-6850 and the SDP. Consequently, we thought it would be appropriate to change the sentence to “The new fire location factors provide a significant reduction in bias and model uncertainty over those recommended in NUREG/CR-6850 [1] and the NRC Significance Determination Process [54], as shown in Table 6-2."

Follow-up: Consider accepting the comment and rewording the sentence.

Conclusions

Approximately three quarters of the CNWRA comments on draft NUREG-2178, Vol. 2 (126 of the 170 submitted) were accepted and nearly all resulted in changes to the document. After an initial check, the resolutions for 10 of the remaining 44 comments were retained for a more detailed review. This review resulted in the following recommended actions:

- CNWRA-5: We recommend that the Office of Regulatory Research consider conducting a study to obtain more accurate values for the radiative fraction and soot yield of various types of electrical cables.

- CNWRA-18*: We propose replacing the last two sentences at the end of the paragraph below the two bullet items at the top of page 2-18 (Starts with "Since the guidance for Kerite-FR cables in …") with the following: "Based on the test results in NUREG/CR-7102 and guidance in FAQ 08-0053 Revision 1, TP damage criteria can be assumed for Kerite-FR cable and TS damage criteria can be assumed for Kerite FR-II, FR-III, and HT cable. Furthermore, TS ignition criteria can be assumed for all Kerite cable types because all varieties are IEEE 383 qualified."

- CNWRA-19: We suggest expanding the discussion in section 2.3.3.3 to better show that the bias in the FDS heat flux calculations combined with the bias in the heat soak method indeed compensates for the error in the heat flux predictions due to the use of the medium resolution grid. More specifically, an estimate of the bias in the heat flux method should be provided and reference should be made to section A.5.

- CNWRA-52*: Check whether references to Figures 5-19 and 5-20 on pages 5-26 and 5-27, respectively are correct.

- Editorial (last sentence in the paragraph at the top of p. 8-4): Suggest changing the sentence to "The new fire location factors provide a significant reduction in bias and model uncertainty over those recommended in NUREG/CR-6850 [1] and the NRC Significance Determination Process [54], as shown in Table 6-2."

References

[1] Yang, J., A. Hamins and T. Kashiwagi, "Estimate of the Effect of Scale on Radiative Heat Loss Fraction and Combustion Efficiency," *Combustion Science and Technology*, vol. 96, pp. 183-188, 1994. doi: 10.1080/00102209408935354

[2] Hamins, A., T. Kashiwagi and R. Buch, "Characteristics of Pool Fire Burning," in *Fire Resistance of Industrial Fluids*, Totten and Reichel, eds., ASTM STP 1284, pp. 15-41, ASTM International, West Conchohocken, PA, 1996. doi: 10.1520/STP1284-EB

[3] Buch, R., A. Hamins, K. Konishi, D. Mattingly and T. Kashiwagi, "Radiative Emission Fraction of Pool Fire Burning Silicone Fluids," *Combustion and Flame*, vol. 108, pp. 118-126, 1997. doi: 10.1016/S0010-2180(96)00098-3

[4] Quintiere, J. and A. Rangwala, "A theory for flame extinction based on flame temperature," *Fire and Materials*, vol. 28, pp. 387–402, 2004. doi: 10.1002/fam.835

[5] Quintiere, J., R. Lyon and S. Crowley, "An exercise in obtaining flame radiation fraction from the cone calorimeter," *Fire and Materials*, vol. 40, pp. 861–872, 2016. doi: 10.1002/fam.2350

[6] Janssens, M., K. Carpenter, S. Turner, and S. Tsuchino, "Experimental Program to Obtain Characteristics of Electrical Cables for Performance-Based Fire Protection of Nuclear Facilities in Japan," in 10th SFPE Conference on Performance-Based Codes and Fire Safety Design Methods, Gold Coast, Australia, Society of Fire Protection Engineers, Gaithersburg, MD, 2014.

APPENDIX A

Results of Initial Review

(Consists of 24 Pages)

RESULTS OF INITIAL REVIEW OF COMMENT RESOLUTION FOR NUREG 2178 VOLUME 2

SUBSTANTIVE COMMENTS

Substantive Comments on Section 1

CNWRA-1 Page 1-2, line 16

Replace "… from fires …" with "… from ignition source fires …" because the new fire location factors do not apply to cable tray fires, for example.

Substantive Comments on Section 2

CNWRA-2 Page 2-1, lines 13

Replace "… discussed …" with "… critically examined …" because the underlying assumptions have been discussed during the NFPA 805 LAR reviews but have not been examined in any detail.

CNWRA-3 Page 2-1, line 35

Replace "… currently used in FPRA applications." with "… currently used in FPRA applications, i.e., for fires that are an order of magnitude smaller in physical size."

CNWRA-4 Page 2-2, line 12

What is "near zero"? Replace "The view factor of the fire from the target is near zero …" with "The flame size is small relative to the distance between the target and the fire …"

CNWRA-5 Page 2-2, line 28

It is common to assume a default value of 0.3 for the radiative fraction. However, this may be too low for cable and other types of fires that need to be considered in an FPRA. For example, the radiative fraction for cable fires can be estimated from the ratio of the radiative to the chemical heat of combustion reported in Table A.39 of the SFPE handbook (5th Edition). The resulting range for the radiative fraction of TP cables (PE/PVC and PVC/nylon/PVC-nylon) is 0.37-0.63 with a mean of 0.50 and median of 0.49. For TS cables (EPR/Hypalon, XLPE/XLPE, and XLPE/neoprene) the range is 0.34-0.62 with a mean of 0.47 and median of 0.50. Consequently, a single range of 0.35-0.63

for the two cable types seems reasonable. This is well above the default value of 0.3. As a result, the target distances in Table 2-1 may be too low (which is non-conservative).

Note: Using a low value for the radiative (or radiant) fraction may have an effect on model results and conclusions presented in other sections of the NUREG. A more detailed examination would be needed to quantify this effect and to determine whether additional calculations with a higher radiative fraction need to be performed.

CNWRA-6 Page 2-3, Table 2-1

Apparently, Heskestad's flame length correlation was used to calculate L_f. That should be stated in the text or a footnote to the table.

CNWRA-7 Page 2-3, lines 10-11

It is suggested to revise the last sentence. Wind effects are (usually) not accounted for in FPRA applications. However, in addition to target orientation the view factor calculation also depends on the physical size of the fire and target distance to the fire.

CNWRA-8 Page 2-4, Figure 2-3

S should be drawn as a cylinder.

CNWRA-9 Page 2-4, lines 19-21

When determining the radiant fraction (e.g., from experiments), the radiative heat transfer to the fuel (i.e., through the bottom surface of the cylinder) is not included. It is therefore suggested to replace the sentence at the bottom of page 2-4 with the following: "The portion of the surface integral in Equation 2-1 over the bottom of the cylinder can be ignored because in determining the radiant fraction (e.g., from experiments), the radiative heat losses to the fuel (i.e., through the bottom surface of the cylinder) are not included. Furthermore, assuming all thermal radiation emitted by the flame passes through the side of the cylinder, the result of integration is shown in Equation 2-2. This assumption is conservative because it results in a higher value for the emissive power, E, and therefore a larger ZOI."

CNWRA-10 Page 2-6, lines 13-16

The part of the paragraph starting with "The emissive power …" and ending with "… periphery of the fire" is confusing and redundant. These sentences can be deleted.

CNWRA-11 Page 2-6, line 21

Replace "… a 30% radiant fraction …" with "… an assumed 30% radiant fraction …" Also, see comment on Page 2-2, line 28

CNWRA-12 Page 2-6, lines 30-36

For consistency it is suggested to use the same term when referring to the heat flux threshold for damage. For example, in line 30, replace "… a higher heat flux …" with "… a higher critical target heat flux …". In line 31, replace "… desired heat flux …" with "actual critical target heat flux …". In line 33, replace "… of the desired heat flux." with "… below the actual critical target heat flux." In Equation 2-6 use $\dot{q}''_{cr,eff}$ and $\dot{q}''_{cr}$ to refer to the adjusted and actual critical target heat flux, respectively.

CNWRA-13 Page 2-7, line 2

Same as previous comment.

CNWRA-14 Page 2-13, lines 6-9

Equation 2-7 is incorrect. The terms inside both parentheses on the right-hand side of the equation should be reversed. For example, (T_{amb} – T_w) should be (T_w – T_{amb}). In addition, there is no need to introduce an effective blackbody radiation temperature by writing the equation as follows:

$$\varepsilon_{in}(E - \sigma T_w^4) + h_{in}\left(T_g - T_w\right) = \varepsilon_{out}\sigma(T_w^4 - T_{amb}^4) + h_{out}(T_w - T_{amb}) \qquad (2\text{-}7)$$

CNWRA-15 Page 2-13, line 11

35 $W/m^2 \cdot K$ seems reasonable, but the cited reference (Eurocode 1-2) deals with fires in structures and does not seem to be applicable here. A better reference is needed.
Page 2-13, lines 13-15

In line 13, replace "Radiative flux …" with "Maximum radiative flux …" because Equation 2-8 is for a target that is facing the center (mid-width and mid-height) of the cabinet panel. Also, use ε_{out} instead of ε in the equation.

CNWRA-16 Page 2-14, lines 9-11

From the description it appears the fire was a gas burner, but that is not stated anywhere.

CNWRA-17 Page 2-14, lines 19-24

Explain what K is in Equation 2-9 and provide the value that was used for K. The units for the convection coefficient in line 23 are $W/m^2 \cdot K$, not $W/m \cdot K$.

CNWRA-18 Page 2-18, lines 16-20*

Guidance for the treatment of different types of Kerite cable in terms of damage and ignition thresholds is provided in the NRC Fire Protection Significance Determination Process (see reference [54], pp. 64-65). This guidance is based on experience from NFPA 805 LAR reviews.

CNWRA-19 Page 2-28, lines 10-15

In lines 14-15 it is stated that the medium grid was used for the simulations. However, in lines 10-11 it is states that there was a 20-30% increase in the predicted heat flux going from the medium to the high resolution. Was a 1.2-1.3 correction factor applied to the heat flux predictions used in generating the results that are presented in Tables 2-3 through 2-6?

CNWRA-20 Page 2-31, lines 13-17

Was the heat soak method described in Appendix used to determine the plume ZOI?

Substantive Comments on Section 3

CNWRA-21 General

For large cabinets with an open top it may be possible for combustion to take place above the cabinet. Is the radiation from such a flame accounted for in the analysis?

CNWRA-22 Page 3-4, 3.1.2 Example

For the two examples, add references to the tables (and documents if not in the present document) where the 98th percentile HRR, unadjusted radiation ZOI, and Obs_Fac can be found. For example, the second sentence would be modified as follows: “This would have a heat release rate (HRR) of 45 kW at 98th percentile (from Table 4-2 in NUREG-2178, Vol.1).”

CNWRA-23 Page 3-7, 3.2.2 Example

This example is difficult to follow. From the first sentence, we can determine we should be able to find the ZOI in Table 2-6 because that is the table to be used for large closed cabinets. However, the description of the cabinet in the first sentence does not provide enough information (fuel content and type of cables not specified) to determine the ZOI. The second sentence indicates both the unvented face damage threshold and integral approach ZOI are equal to 0.59 m. According to Table 2-6, a 285 kW fire is the only fire in a closed large electrical cabinet that results in a ZOI of 0.59 m (both approaches) for a TP target. At this stage we know that the fuel loading is the default loading but we still don't know whether the cabinet contents are TP or TS cable. From the fourth sentence and Table 3-3 we can then determine the cable type is TS (because the maximum severity factor is 0.10). Finally, Table 2-6 indicates a TP target at 0.25 m from an unvented face of the cabinet with TS contents would still be damaged at an HRR of 202 kW (93rd percentile HRR) but not at 155 kW (90th percentile HRR). Consequently, the severity factor for the cable is between 0.07 and 0.1 and slightly higher than 0.07.

It would be helpful to describe this example in more detail. In addition, it is not clear at the start of the example what the purpose is of this example. It becomes clear later on that the example provides a comparison between the maximum severity factor in Table 3-3 or 3-4 and the more accurate value determined from the ZOI tables in Section 2.

CNWRA-24 Page 3-13, line 28

Replace "… for the medium cabinet." with "… for the small cabinets."

Substantive Comments on Section 4

CNWRA-25 Page 4-5, lines 19-20

This statement is generally true, except for some types of Kerite cable (see reference [54], pp. 64-65).

CNWRA 26 Page 4-10, lines 22-32

It is stated that there were zero occurrences of cabinet to cabinet fire spread in 130 cabinet fire events. Based on this observation, the likelihood of multi-enclosure fire experience is estimated at 0.5/131 = 0.0038 because the 131 events include fires in electrical enclosures for which fire spread to adjacent enclosures would not be postulated based on the guidance in Section 4.2.3. Consequently, the 0.0038 estimate is low and to obtain a more accurate estimate the denominator in the equation (131) should be reduced by subtracting the events that involved electrical enclosures and configurations for which fire spread would not have been postulated. It is probably not possible to identify all these events from the information in the FEDB but at least the denominator could be reduced by subtracting the number of switchgear and MCC fires.

CNWRA-27 Page 4-12, lines 11-16

Postulating fire spread to either side with a conditional probability of 0.01 may be more practical but could significantly underestimate the risk.

CNWRA-28 Page 4-13, lines 1-10

Most figures in Section 9.2.3 in NUREG/CR-7010, Vol. 1 do not show that the fire intensity (HRR) reaches a peak value that is roughly steady over time.

CNWRA-29 and CNWRA-30 Page 4-13, Section 4.4.2

NUREG-2230 introduces the concept of interruptible cabinet fires. How would these fires affect the guidance provided in Section 4.4.2?

CNWRA-31 Page 4-15, line 41

Add a sentence to clarify that, for an interior cabinet in a bank, fire spread can be postulated to the adjacent cabinet on either side but not to both in the same scenario.

CNWRA-32 Page 4-16, Figure 4-1

At the end of the steady burning period the HRR is supposed to abruptly transition to a linear decay. In this figure the HRR gradually transitions from the steady burning period to the linear decay (it looks like the “smoothed line” was turned on in Excel). Please correct.

Substantive Comments on Section 5

CNWRA-33 General

This section describes several Monte Carlo analyses in which a set of input parameters are varied in a random manner within a specified range. For most parameters, no basis is provided for the range that was chosen. For example, on page 5-8, line 21 it is stated that the fraction α is postulated to range between 40% and 80% of the motor casing length but no basis for the assumed range is provided. The basis could be more qualitative than quantitative, but it still should be provided.

CNWRA-34 Page 5-2, line 20

The FEDB is reference [35].

CNWRA-35 Page 5-8, lines 21 and 24

See general comment.

CNWRA-36 Page 5-9, line 21

What does "burn with a low flame heat flux" mean? These products are difficult to ignite and have a low heat release rate.

CNWRA-37 Page 5-9, line 27

See general comment.

CNWRA-38 Page 5-9, Footnote

A negative heat release rate is not physical. It may be helpful to briefly explain how HRR_0 is determined. Essentially, specimens of a material are tested in the cone calorimeter or similar device to measure the heat release rate as a function of radiant heat flux. The measured HRRPUA (usually the peak value) is plotted versus heat flux, a straight line is fitted through the data points and HRR_0 is determined as the intercept of the linear fit with the ordinate (HRRPUA axis). Lyon's group at the FAA has shown that polymeric materials with a HRR_0 greater than 100 kW/m^2 are unlikely to pass a small-scale flammability test such as the UL 94 vertical flame test. Materials with a negative or very low HRR_0 require an external heat source to sustain flaming combustion.

CNWRA-39 Page 5-10, line 5

See general comment.

CNWRA-40 Page 5-10, line 10

Are all variables assumed to be uniformly distributed?

CNWRA-41 Page 5-12, Table 5-2

How were the motor length and radius ranges determined for each rating determined?

CNWRA-42 Page 5-13, line 15

See general comment.

CNWRA-43 Page 5-13, line 22

See general comment.

CNWRA-44 Page 5-13, line 31

See general comment. What is meant by “observed”?

CNWRA-45 Page 5-13, line 33

What is meant by “observed”? In this case the range was determined on heat of combustion data for the different jacketing materials that are used.

CNWRA-46 Page 5-14, Table 5-4

See comment for Table 5-2.

CNWRA-47 Page 5-15, lines 4-6

How were the growth, steady burning and decay durations determined?

CNWRA-48 Page 5-25, lines 15 and 20

See general comment.

CNWRA-49 Page 5-25, Figure 5-19

What is the purpose of showing a single cylinder? It is unlikely that L in this part of the figure is the widest dimension of the external transformer housing.

CNWRA 50 Page 5-26, lines 21-22

See general comment.

CNWRA-51 Page 5-26, lines 25-26 and lines 40-42

Six out of twenty-eight (21.4%) outcomes that lead to ignition of all three cylinders does not seem to be consistent with the statement in lines 25-26.

CNWRA-52 Page 5-27, line 13*

Should this refer to Figure 5-19?

CNWRA-53 Page 5-28, line 17

Replace "… in each classification group …" with "… for each power rating …"

CNWRA-54 Page 5-29, Table 5-7

How were the coil height and radius ranges determined for each rating determined?

CNWRA-55 Page 5-29, line 15

It is not clear which distributions are nearly indistinguishable.

CNWRA-56 Page 5-30, line 27

See general comment.

CNWRA-57 Page 5-30, line 35

See general comment.

CNWRA-58 Page 5-31, Table 5-9

Same comment as for Table 5-2.

CNWRA-59 Page 5-33, line 12

Replace "… resulting maximum horizontal …" with "… resulting maximum vertical …"

CNWRA-60 Page 5-35, line 6

Is the use of a fixed Froude number of 1.0 justified?

CNWRA-61 Page 5-38, line 28

Same as previous comment.

Substantive Comments on Section 6

CNWRA-62 Page 6-2, line 5

Add the following at the end of the sentence: "… and $\dot{q}''$ is the HRRPUA (kW/m^2)."

CNWRA-63 Page 6-6, Figure 6-3

A possible explanation why the experimental values are consistently lower than the model predictions is that the radiant fraction was underestimated in the calculations (see comment on page 2-2, line 28). Moreover, the predictions based on the image method are consistently higher than for the FDS calculations because the former essentially assumes that the walls are perfectly insulated while the latter takes heat losses through the walls into account. It is suggested to add these observations to the discussion of Figure 6-3 on page 6-5.

CNWRA-64 Page 6-7, Figure 6-4

Same as previous comment.

Substantive Comments on Section 7

Note: This section is virtually identical to section 3.5.2 in NUREG-2230. CNWRA comments are therefore nearly identical to the comments submitted based on its review of the corresponding section in NUREG-2230.

The discussion on the NSP floor was moved / resolved into NUREG-2230

CNWRA-65 Page 7-1, line 18

Add "The latter is usually 24 hours (see NUREG-2122)." at the end of the paragraph.

CNWRA-66 Page 7-1, line 28

For the MCB frequency, refer to Table 8-3 instead of Chapter 8.

CNWRA-67 Page 7-1, line 33

For the electrical cabinet frequency, reference is made to NUREG-2230. The citation can be more specific (the value is provided in Table 3-9 of NUREG-2230).

CNWRA-68 Page 7-1, lines 35

Provide a basis for the 300-700 range of the number of cabinets counted as ignition sources in a single unit NPP. This seems inconsistent with the average plant-wide count of 750 in Table 6.2.3 of IMC 0308 Attachment 3 Appendix F [54].

CNWRA-69 Page 7-2, lines 4-6

Provide a basis for the 10%-30% range of the apportioning factor (fraction of the control, auxiliary and reactor building floor area representing the MCR).

CNWRA-70 Page 7-2, lines 12-14 and Equation 7-1

Delete the sentence “This results … 1.21E-4/day.” because this calculation is incorrect, as it does not account for the random variables (total number of cabinets in the plant and apportioning of the area of the MCR). Instead, change Equation 7-1 as follows:

$$Pr(t \leq 24\ h) = (3.7\text{E-}03)/365 \approx 1\text{E-}05 \qquad (7\text{-}1)$$

CNWRA-71 Page 7-2, line 26

According to NUREG-2178, Volume 1, the 98th percentile peak HRR of a large open electrical enclosure with thermoplastic cable contents is 1,000 kW. Five minutes after ignition the fire in such a cabinet would grow to 174 kW. Three minutes after ignition the HRR is 63 kW. A value closer to 3 minutes may be a more appropriate lower limit for the range.

CNWRA-72 Page 7-2, line 41

Explain how the non-suppression floor value for a dual unit MCR was estimated.

Substantive Comments on Section 8

CNWRA-73 Page 8-1, line 16

What are the two characteristics that are being referred to in the sentence that starts with "These two characteristics …"

CNWRA-74 Pages 8-23 and 8-24, Table 8-10

The radiant fraction is assumed to be 0.3. As discussed before, this value may be too low for MCB fires.

The HRRPUA is assumed to range between 150 and 500 kW/m^2. The lower limit is the generic value for TP cable but no basis is provided for the upper limit.

CNWRA-75 and CNWRA-76 Pages 8-24 through 8-29, Table 8-11

Provide references and include citations of the reports that describe the tests for which selected results are presented in the table.

CNWRA-77 Page 8-30, line 18

Exactly which guidance in Section 3 is being referred to?

CNWRA-78 Page 8-31, line 2

For the floor value refer to Table 7-1 or include a citation of NUREG-2230.

CNWRA 79 Page 8-31, line 10

For the updated manual suppression rate refer to Section 8.3.3 or Table 8-6.

CNWRA 80 Page 8-33, line 3

Replace "… effect …" with "… affect …"

CNWRA 81 Page 8-34, lines 1-3

Add the underlined words in the first line: "The values of δ for Very Low fuel loading …"

CNWRA 82 Page 8-34, lines 4-6

Assuming a single value of 0.126 will result in underestimating the probability for spread for 11 of the 32 cases. Is that acceptable?

CNWRA 83 Page 8-39, lines 5-7

The table numbers are incorrect. They should be 8-6, 8-18, and 8-19 instead of 8-7, 8-15, and 8-18, respectively.

CNWRA 84 Page 8-40, Table 8-18

Replace "… for enclosures with no in-cabinet detection." with "… for <u>large closed</u> enclosures with <u>default TP fuel loading and</u> no in-cabinet detection." in the description for $P_{ns}(t_1)$

Substantive Comments on Section 9

CNWRA 85 Page 9-1, lines 3-5

Replace "… and fire location factor …" with "… and fire base elevation …"

CNWRA 86 Page 9-2, lines 1-4

The growth, steady burning and decays times should be 2, 13, and 2 minutes, respectively.

CNWRA 87 Page 9-3, lines 33-35

Replace the first sentence (starts with "Section 6 …" and ends with "… and corners." with the following two sentences: "Section 6 summarizes the latest guidance for determining plume temperatures for fires postulated in a corner or along a wall. The section provides validation of the new fire location factors based on the National Institute of Standards and Technology (NIST) experiments near walls and corners."

CNWRA-88 Page 9-4, line 2

Delete the following sentence: "Definitions of wall and corner configurations are presented in Section 6.1." There are no such definitions in Section 1.

Substantive Comments on Appendix A

CNWRA-89 Page A-1, line 17

Replace "… inner jacket temperature …" with "… jacket inner temperature …".

CNWRA-90 Page A-1, lines 23-24

Replace "… without the data processing and modeling time requirements …" with "… without the time consuming input data gathering and output data processing requirements …"

CNWRA-91 Page A-1, line 31

Replace "… report …" with "… Appendix …" Make this change throughout the Appendix.

CNWRA-92 Page A-2, line 11

Replace "… are discussed methodology …" with "… are discussed in the section describing the methodology …"

CNWRA-93 Page A-11, line 5

Add the following (underlined part) at the end of the sentence: "… (sizes and jacket and insulator materials) exposed to a constant radiant heat flux."

CNWRA-94 Page A-11, line 6

Add the following (underlined part) to the words in parentheses: (model predicts faster time to failure)".

Substantive Comments on Appendix B

CNWRA-95 Page B-1, Table B-1

Using the threshold approach for open TP and TS cabinets, the Obs_Fac for default fuel loading is equal to or smaller than the value for low fuel loading. For all other cases in Table B-1 and all cases in the corresponding Table 3-1 for the unadjusted FTD^s, the Obs_Fac is larger for default fuel loading compared to low loading. Is this a typo or is there a plausible explanation for the reversal?

CNWRA-96 Page B-2, Table B-2

Same as previous comment but for vented cabinets faces of large open cabinets with TP cable contents. The corresponding Obs_Fac values for the unadjusted FTD^s are provided in Table 3-2.

Substantive Comments on Appendix D

CNWRA-97 Page D-2, line 7*

The vent approximately 0.3 m above the bottom of the enclosure in Enclosure A is not shown in Figure D-1.

CNWRA-98 Pages D-6 through D-9, Figures D-2 through D-6

At the end of the steady burning period the HRR is supposed to abruptly transition to a linear decay. In the figures, the HRR gradually transitions from the steady burning period to the linear decay (it looks like the "smoothed line" option was turned on in Excel). Please correct.

CNWRA-99 Page D-14, line 4

The time to failure would be approximately 19 minutes if the HRR evolution in Figure D-2 is applicable to this example.

EDITORIAL COMMENTS

General Editorial Comment

Throughout the document, volume 1 of NUREG-2178 is referred to as “NUREG-2178” without specifying the volume. For those citations it is suggested to either add the volume (i.e., use “NUREG-2178, Vol.1” instead of “NUREG-2178”) or include a statement in Section 1 to explain that citations of NUREG-2178 throughout the document actually refer to volume 1 of the NUREG. The same comment applies to NUREG/CR-6850, Vol. 2.

Editorial Comments on the Executive Summary

Page vii, line 15

Replace “… group composed …” with “… group was composed …”

Page viii, line 8

Replace “… expertise implementing the methods …” with “… expertise from implementing and supplementing the existing methods …”

Page viii, line 23

Delete “are discussed”.

Editorial Comments on Section 1

Page 1-1, line 28

Delete “, including”.

Page 1-2, line 4

Replace “… NUREG/CR-6850 …” with “… NUREG/CR-6850, …” (comma added).

Note: This is an example of a reference to NUREG/CR-6850, Vol. 2 where the volume is not specified (see general editorial comment above)

Page 1-3, line 31

Replace "… presented including…" with "… presented, including …"

Page 1-3, lines 35-36

Replace "… on implementing the results and insights of the Fire Dynamics (FDS) simulation on …" with "… for implementing the results and insights of the Fire Dynamics (FDS) calculations of …"

Page 1-4, line 6

Replace "… is a consideration …" with "… need to be considered …"

Page 1-4, line 7

Replace "… in a corner location and when …" with "… in a corner, and to determine when …"

Editorial Comments on Section 2

Page 2-1, line 11

Replace "… use of field model …" with "… use of a field model …"

Page 2-1, lines 24-25

This sentence seems out of place and can/should be deleted.

Page 2-2, line 3

It is custom to use $\dot{Q}$ for heat release rate and $\dot{q}$ for heat flow (and therefore $\dot{q}''$ for heat flux).

Page 2-7, line 18

Replace "… representative of a large …" with "… representative of large …"

Page 2-8, line 11

Replace "… are large fires." with "… are larger."

Page 2-12, line 12

Add volume and dimensions in SI units, i.e., "1.78 m^3 (0.91 × 0.91 × 2.13 m)".

Page 2-14, line 6

Replace "… inside the cabinet with the door open." with "… inside the cabinet <u>in the tests</u> with the door open."

Page 2-17, line 10

Replace "… high values resulting in unrealistic (conservative) target damage." with "… high values <u>and, therefore,</u> in unrealistic (conservative) target damage <u>estimates</u>."

Page 2-19, line 6

Add the following sentence at the end of the paragraph: "An example of the latter is shown in Figure 2-16."

Page 2-20, lines 12-15

Strictly speaking, a 50 ft^3 is not a large cabinet. Is there a difference between m50 and l50? In addition, the unit conversions are soft conversions. Which units are exact?

Page 2-21, line 6

Where is the SE corner? If directions are important, it would be helpful to show which direction is north in Figure 2-17.

Page 2-22, lines 5, 13-14, and 17

Same as previous comment.

Page 2-25, line 17

Delete "that".

Editorial Comments on Section 3

Page 3-2, line 6

Replace “… Obs_Fac are …” with “… Obs_Fac values are …”

Page 3-13, line 24

Replace “… footprint (the …” with “… footprint (they …”

Page 3-15, line 2

Replace “… ORIENATION …” with “… ORIENTATION …”

Page 3-15, line 31

Replace “… the fuel was …” with “… if the chemical formula of the fuel was specified as …”

Editorial Comments on Section 4

Page 4-2, line 10

Replace “… in fire protection/fire modeling literature.” with “… in the fire protection/fire modeling literature.”

Page 4-2, line 13

Delete “and examples“ because the examples are in Appendix D as stated in line 21.

Page 4-2, line 31

Replace “… methodology require …” with “… methodology requires …”

Page 4-2, lines 15-16

Replace “… both the NRC-RES/SNL [30] tests and the NUREG/CR-7197 fire tests …” with “… both the NRC-RES/SNL [30] and NUREG/CR-7197 fire tests …”

Page 4-14, line 47

Replace "… as necessary to the analysis goals …" with "… as necessary to meeting the analysis goals …"

Editorial Comments on Section 5

Page 5-1, line 25

Replace "Examples applications …" with "Example applications …"

Page 5-7, line 32

Replace "… Supplement 1 states …" with "… Supplement 1 to NUREG/CR-6850 states …"

Page 5-8, line 2

Delete "that is assumed to be flammable." at the end of the sentence.

Page 5-8, line 18

Replace "… motor casing is assumed …" with "… motor casing that is assumed …"

Page 5-8, line 26

Replace "… estimation pairs …" with "… estimates …"

Page 5-14, line 13

Delete "well with the NUREG/CR-7010 [24] calculations" because it is redundant with the rest of the sentence.

Page 5-14, line 14

Replace "… method consistently …" with "… method, the latter consistently …"

Page 5-14, line 15

Replace "… provides rationale …" with "… provides a rationale …"

Page 5-17, lines 2-3

Replace the sentence with “The maximum HRR can be estimated using the dimensions listed above, the Solid Flame II radiation model, and Heskestad’s fire plume model [3,38].”

Page 5-17, line 12

Remove hard return.

Page 5-19, line 6

Replace “… assign transformer …” with “… assign a transformer …”

Page 5-20, line 19

Spell out BWR or use the acronym for both types of reactors.

Page 5-23, line 5

Make “Dry-Transformer” plural.

Page 5-28, line 2

There does not appear to be a reference to this figure in the text.

Editorial Comments on Section 6

Page 6-1, line 19

Replace “… corners or wall surfaces …” with “… a corner or a wall surface …”

Page 6-1, lines 19-22

Replace the sentence “The fire location factor … along walls.” with “The fire location factor, k_F, is used in calculating plume temperatures for an ignition source fire that is located in a corner or along a wall. Its effect is to increase the plume temperature at a specified elevation compared to that for the same ignition source fire in the open.”

Page 6-3, line 43

Replace "… corners or along walls …" with "… a corner or along a wall …"

Editorial Comments on Section 7

Page 7-2, lines 26-27

Replace "… occurs before a half of the Growing …" with "… occurs before half of the Growing …"

Page 7-4, Figure 7-1

"Growth Fire" is referred to as "Growing Fire" in other places. Strictly speaking, the lower limit for the y-axis is 0.00001. It would be better to print the axis labels and titles and the text in the legend in black.

Editorial Comments on Section 8

Page 8-7, lines 24 and 26

Replace "… a MBC …" with "… an MBC …"

Page 8-7, line 33

Replace "… were …" with "… are …"

Page 8-10, Figure 8-2

The text is hard to read. The font size should be large and the text should be printed in black.

Page 8-11, Figure 8-4 and Page 8-12, Figure 8-5

Same as previous comment.

Page 8-13, line 10

Replace "… liner …" with "… linear …"

Page 8-16, Figure 8-9

Axis labels and titles and legend text should be printed in black.

Page 8-23, Table 8-10

The gamma distribution parameter in the heading of the fourth column should be β. In the notes column, the reference should be corrected or added for the MCR Suppression Rate (Section 8.3.3 or Table 8-6) and the NSP floor value (Table 7-1 or NUREG 2230).

Editorial Comments on Section 9

Page 9-1, line 30

Delete “air gap”.

Page 9-1, line 35

Replace “… fuel (exposing) …” with “… fuel loading (exposing) …”

Page 9-1, lines 33 and 36-37

Make items plural.

Page 9-2, line 14

Should refer to Table 9-1 instead of 8-1.

Page 9-4, line 2

Replace “… factor provides …” with “… factors provide …”

Page 9-4, line 3

Insert “over those recommended in NUREG/CR-6850 [1] and the NRC Significance Determination Process [54]” after “uncertainty”.

Page 9-4, line 8

Replace “… floor …” with “… floor <u>value</u> …” (2x)

Editorial Comments on Appendix A

Page A-1, line 11

Delete “and”.

Page A-1, line 15

Insert “Supplement 1 to” before “NUREG-1805”.

Page A-11, line 8

Replace “… cables tests …” with “… cable tests …”

Editorial Comments on Appendix D

General

There are some inconsistencies in the capitalization of certain words (enclosure, exposed, exposing, etc.) For example, in some cases “Enclosure” is used but sometimes “enclosure” is used.

Page D-1, Figure D-2

This figure also shows the HRR profile for fires that spread from enclosure 5 to enclosure 4 and from enclosure 5 to enclosure 6.

Page D-7, line 7

Replace “… Figure D-4 and D-5.” with “… Figure D-4, D-5, and D-6.”

Page D-14, line 11

Closing parentheses are missing.