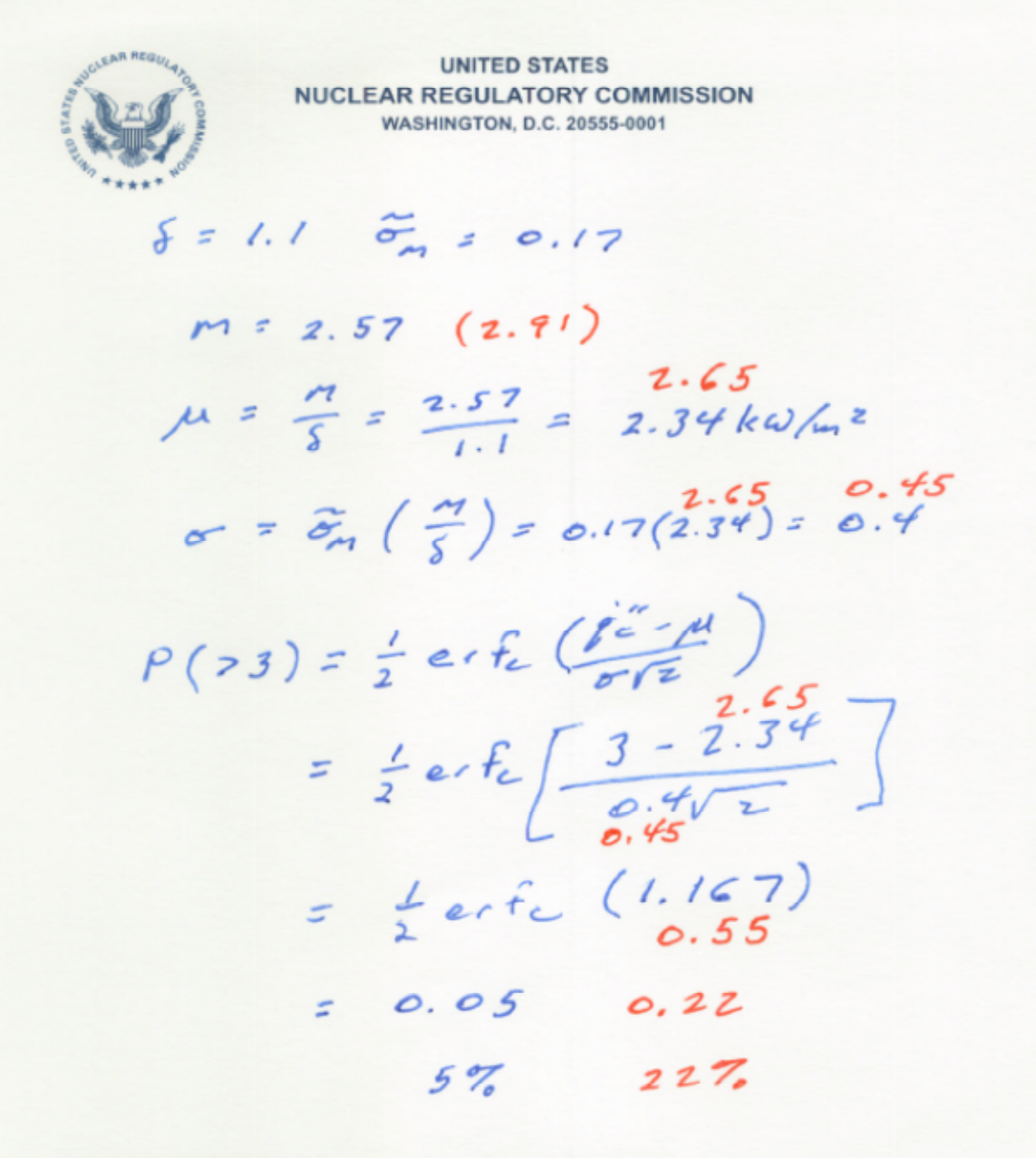
Comments on Sensitive Electronics FAQ

Attached sensitivity analysis

The values came directly from NUREG-1934 for the uncertainty values associated with radiant heat flux (1.10, .17). Given their results the lowest predicated heat flux in the cabinet was 2.57. For this value there is a 5% chance of exceeding the threshold of 3kw/m$^2$. For the highest predicted temperature 2.91, there is a 22% chance of exceeding the critical heat flux value.



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

$\delta = 1.1 \quad \tilde{\sigma}_m = 0.17$

$m = 2.57 \quad (2.91)$

$\mu = \frac{m}{\delta} = \frac{2.57}{1.1} = 2.34 \text{ kw/m}^2 \quad 2.65$

$\sigma = \tilde{\sigma}_m \left(\frac{m}{\delta}\right) = 0.17(2.34) = 0.4 \quad 2.65 \quad 0.45$

$P(>3) = \frac{1}{2} erfc\left(\frac{\dot{q}''_c - \mu}{\sigma\sqrt{2}}\right)$

$= \frac{1}{2} erfc\left[\frac{3 - 2.34}{0.4\sqrt{2}}\right] \quad 2.65 \quad 0.45$

$= \frac{1}{2} erfc\,(1.167) \quad 0.55$

$= 0.05 \quad 0.22$

$5\% \quad 22\%$

**Comment Response:** Independent verification agrees with above calculations of uncertainty. The model uncertainty is considered to be mitigated by safety margins in the analysis. Conservatisms include modeling of the 98$^{th}$ percentile fire HRR, use of a high HRRPUA based on mix of plastics and cardboard, use of fire growth profile and duration that bound similar fires in FAQ-0052, and use of screening damage criteria. The latter, for example, is conservative when compared to critical heat fluxes for plastics based on SFPE Handbook, Table 3-4.2, none of which are lower than 8kW/m².

Additional Comments

1) Fig 7, the initial temperature of 35 C drops back to 25 C in a few minutes. The authors have just initialized the gas temperature to 35 C. At the start of the cabinet, the hot gas just flows out and doesn't heat up again until the radiated heat penetrates the cabinet wall. In reality, the entire cabinet would be 35 C and it wouldn't cool off so readily.
    a. Possibly add an additional heat source in the form of another vent

**Comment Response:** A sensitivity run was performed which placed a series of heating rods to represent the heat produced by the internal components of the cabinet. A total of 20 rods measuring (L x W x H) 0.05m x 0.05m x 1.8m were used. Each rod emits 0.14 kW/m² convective heat flux. This maintains the cabinet at 35°C (without fire exposure).

Results of this sensitivity analysis confirm that the inside of the cabinet would not reach damaging conditions.

**Table 1: Results Comparison with Internal Heat Source**

| | Base Case (as previously reported) | Sensitivity with heater | Delta |
|---|---|---|---|
| Max internal temp. [°C] | 44 | 49 | 5 |
| Max control temp. [°C] | 43 | 44 | 1 |
| Max internal heat flux [kW/m²] | 2.91 | 2.89 | -0.02 |
| Max control heat flux gauge [kW/m²] | 11.27 | 11.24 | -0.03 |

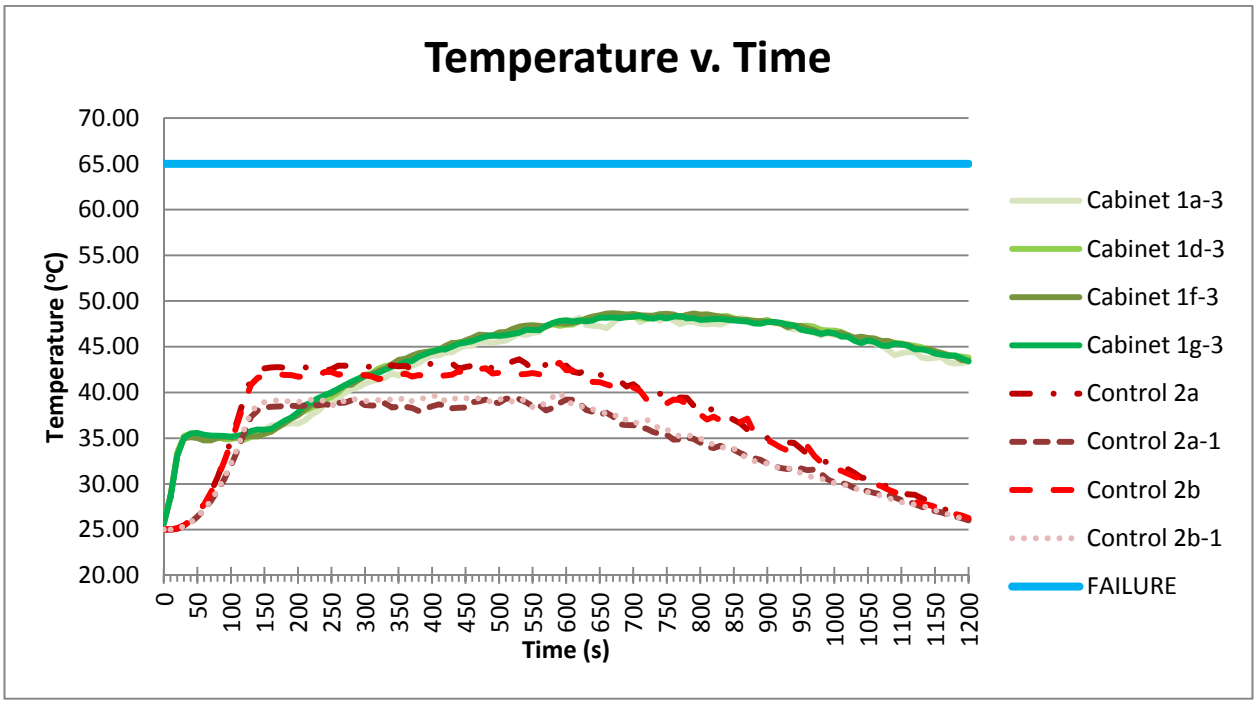



**Figure 1: Temperature Results with Internal Heat Source**

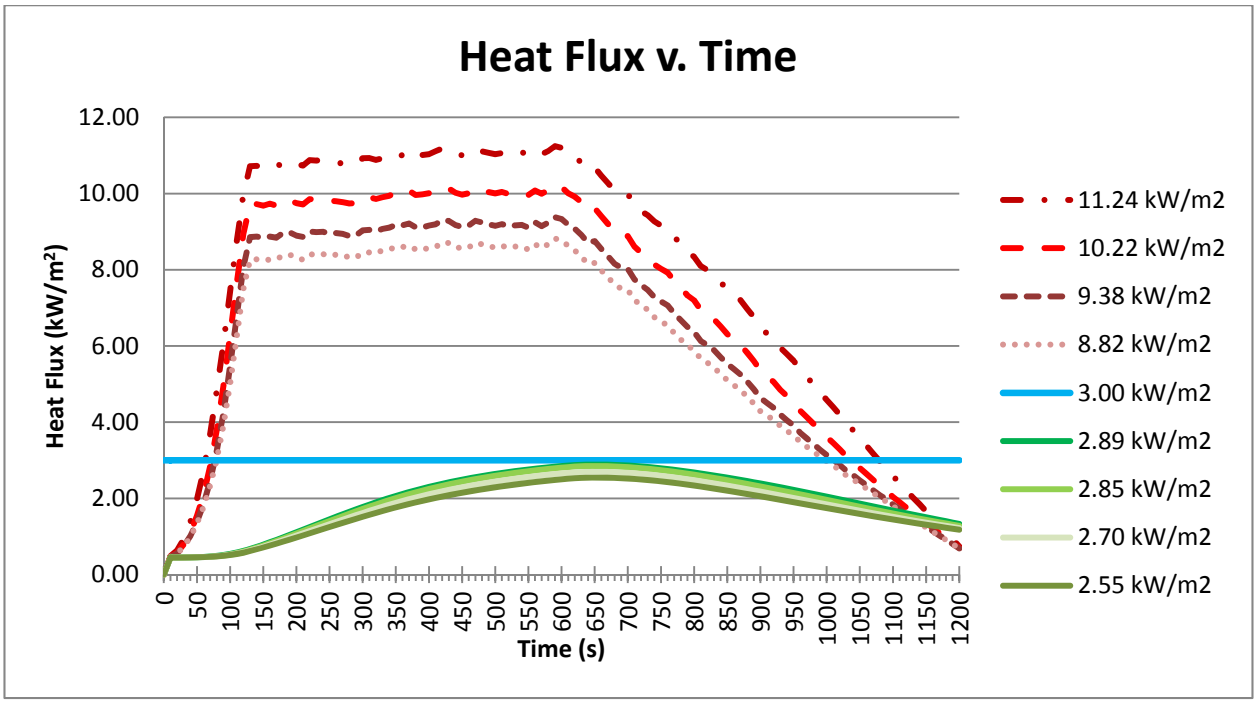



**Figure 2: Heat Flux Results with Internal Heat Source**

2) One minor policy issue – you may not want this statement to set a precedent:
    a. Bottom of page 6: Since the model was not used outside of the limitations identified, it is concluded that the FDS predictions of heat flux is within experimental uncertainty.
    Within the V&V limits does NOT imply within experimental uncertainty.

**Comment Response:** Agree. The statement has been modified to state that the model was used within the limitations discussed in NUREG-1824. The preceding paragraphs on page 6 address experimental uncertainty.

3) Placing the fire in the same plane as the floor also does not match the scenario that the analysis claims to address. This decision affects fire entrainment and therefore could also affect the results.

**Comment Response:** The analysis models a floor based transient fire, and it is the consensus of the FAQ writing team that placing the fire at the floor is the best representation of the scenario. That being said, previous sensitivity analyses had been conducted which indicate that the fire elevation does not significantly impact the results. The peak heat flux measurements are experienced approximately 0.3 meters above the fire elevation. As the fire elevation is increased, in the sensitivity runs, the peak damaging conditions move upward, accordingly.

4) The absence of a REAC input tells us that authors either failed to specify a fire source or consciously chose to use the default propane fire in FDS. While this probably won't change the results much, the model does not match the analysis.

**Comment Response:** A sensitivity run was performed using a REAC input for polyurethane (chosen as a representative for trash mix of plastics and paper). The following inputs were used:

**Polyurethane:**
&REAC ID='POLYURETHANE',
FYI='NFPA Babrauskas',
C=6.3,
H=7.1,
O=2.1,
N=1.0,
SOOT_YIELD=0.1/
Net Heat of Combustion: 22700 kJ/kg

Results of this sensitivity analysis indicate that damaging conditions are not reached within the cabinet.

**Table 2: Results Comparison with REAC Input**

| | Base Case (as previously reported) | Sensitivity with REAC = Polyurethane | Delta |
|---|---|---|---|
| Max internal temp. [°C] | 44 | 45 | 1 |
| Max internal heat flux [kW/m²] | 2.91 | 2.87 | -0.04 |
| Max control heat flux gauge [kW/m²] | 11.27 | 11.00 | -0.27 |

5) The FDS model only considered the radiative heat flux on the inside of the cabinet instead of net, i.e., radiative plus convective. This probably would not affect the results.

**Comment Response:** Convective heat flux devices are required to be assigned to a solid surface within the cabinet. Assigning the devices to a solid surface causes the devices to have thermal inertia dictated by the solid surface properties it is assigned to. By using the "radiative heat flux gas" devices, the model is analyzing the heat flux at a point in space. The device essentially works as a radiometer. Without the thermal inertia on the device imposed by the surface it is attached to, measurements obtained in the model using these devices are more conservative than convective heat flux measurements at solid surfaces; therefore, using radiative heat flux gas-phase devices within the model is considered appropriate and modeling convective heat flux would not be expected to affect the results.

Further, adding solid surfaces with thermal properties inside the cabinet could limit the use and application of the model. The material properties defined for the internal solid surfaces would potentially need to be compared to material properties of the solid surfaces in actual cabinets.

6) The FDS model analyzed two locations inside the cabinet but nothing in between. It is possible that if the equipment is located closer to the surface of the cabinet, it would experience a higher exposure. Considering the uncertainty or sensitivity of the model, this could change the results unless it can be concluded that sensitive equipment is always located at the rear of the cabinet, for instance.

**Comment Response:** The results reported in the analysis are based on the worst case conditions experienced for devices located at the front-most portion inside the cabinet, closest to the fire. These conditions are then assumed to occur anywhere inside the cabinet and therefore if damaging conditions are reached at this location, the cabinet is considered failed. General mounting practices, as evidenced by visual inspection of several cabinets in the field, have shown that sensitive components are generally positioned on internal mounting brackets at least 0.1 meters away from the surface of the cabinet wall, and are not mounted directly to the exterior walls. Further, the FAQ contains a provision that "The component is not mounted on the surface of the cabinet

(front or back wall/door) where it would be directly exposed to the convective and/or radiant energy of an exposure fire," which applies in this case.

**Comment A4 within the FAQ: The structure of this paragraph probably needs to change to address the separate concepts of heat flux and damage temperature. Right now, the discussion intermixes the two to the extent that I'm not sure it is totally correct.**

The analysis did not focus on external surface temperatures of the cabinet. Therefore suggested re-wording:

"FDS simulations for this study found that the heat flux and temperature experienced by components within the enclosure remained below that specified in Section H.2 of NUREG/CR-6850 for sensitive electronic equipment (65°C), while the exterior surface ~~temperature~~ heat flux exceeded the generic screening damage threshold for thermoset cables. These results support the recommendation that a heat flux ~~and/or a~~ generic screening thermal damage threshold for thermoset cables, as observed on the outer surface of the cabinet, can be used as a conservative surrogate for assessing the potential for thermal damage to solid-state and sensitive electronics within an electrical panel (cabinet)."