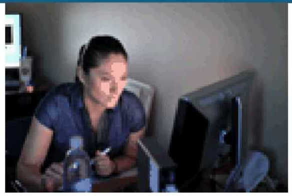
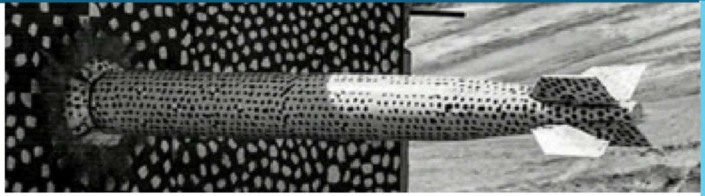
SAND2019-14269PE

Infrared Hazard Regions Calculations





Presented by

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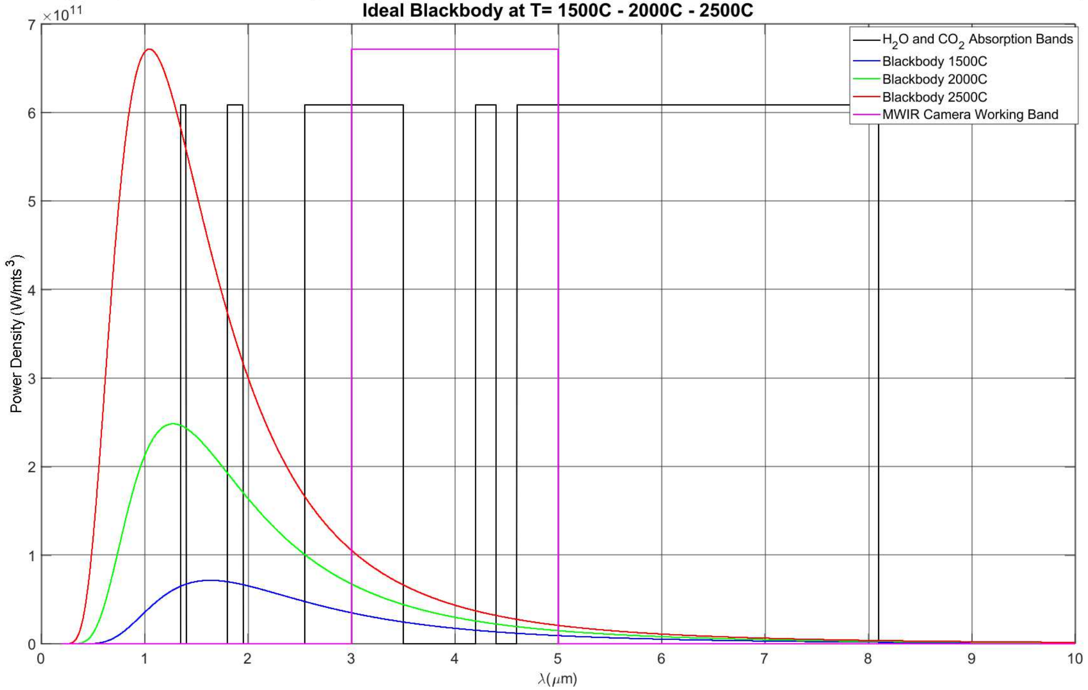
IR Data Constrains – pt 1

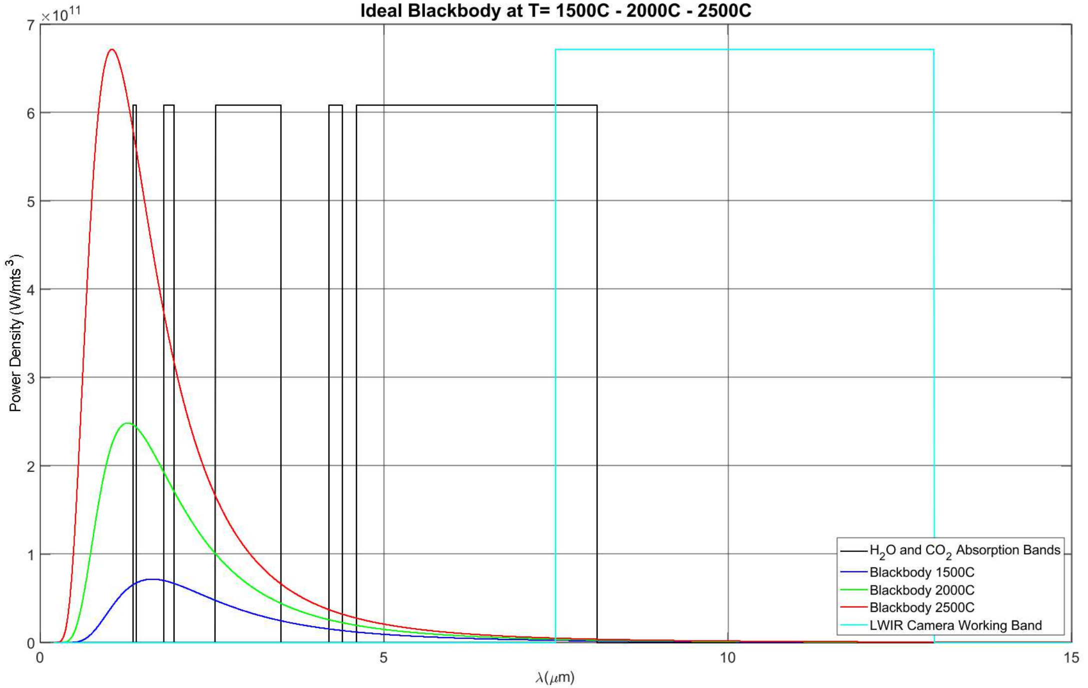
- IR cameras are calibrated assuming that the temperature of an object is radiating as a blackbody (emissivity of 1) or gray body (emissivity < 1), following the Planck curve – **Same temperature across all wavelengths**.



- With an electric arc **we cannot assume** that it is emitting in a continuous way as a blackbody (or gray body) through a full wavelength range.
- The MWIR camera, used at DTE site and KEMA with a wavelength range of 3-5µm, imaged light that follows the shape of the of the arc seen in the visible, from this:
  - we can assume the arc is emitting in the IR, or
  - It is heating up molecules that can re-emit at that wavelength range (e.g. CO_2 an H_2O).

IR Data Constrains – pt2

- At the DTE site we had imaged open box arc faults using LWIR (slow frame rate cameras) with ranges of 7.5 to 13 µm that **report similar temperatures as the MWIR camera** of around 1200-1600C assuming an emissivity of 1.



- This makes us believe there is a continuum of IR emissions between the WMIR (3-5µm) and the LWIR (7.5-13µm) ranges.
- While feasible that there is not such a continuum, it is harder to explain that there is no continuum.
- **With the available data we will assume** that data from the MWIR camera is valid for the 3-13µm range.

IR Data Constrains – pt3

- The ring hazard area calculations **use emissivity of 1**
- We expect the actual temperature of the arc is much higher; implying much lower emissivity numbers if we want to match expected temperatures
- However, the **hazard from radiation in the IR** is related only to the number of photons emitted by the arc fault, and for that we don't need to know the temperature of the arc, just the amount light incident on the camera.

Pain Thresholds

- To calculate the pain thresholds it was used chapter 7 from "Fundamental Studies In Engineering 5: Explosion Hazards and Evaluation" W.E. Baker, et. al.

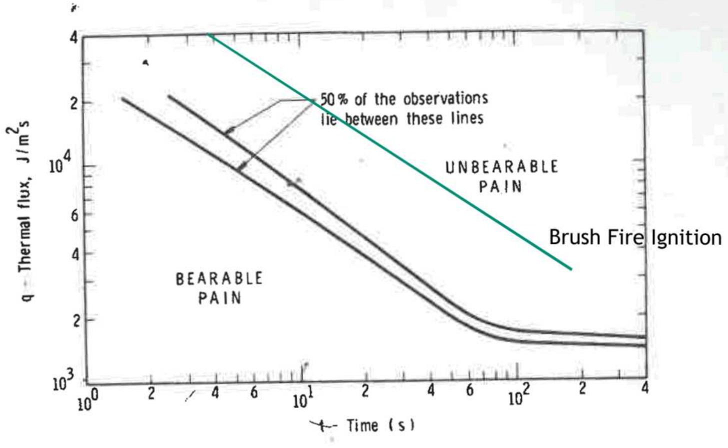


Figure 7-10. Threshold of Pain From Thermal Radiation on Bare Skin [Buettner (1950)]

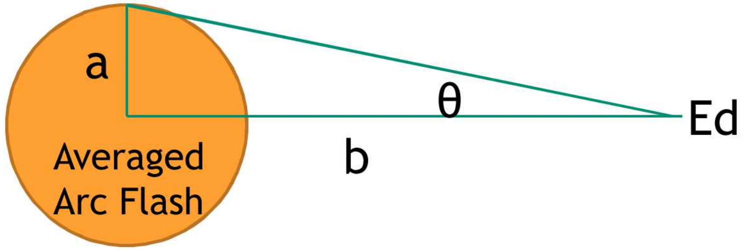
- These curves relevant point is the dependency to exposure times when finding the thermal fluxes for the threshold of unbearable/bearable pain.

- Knowing the duration of the arc, we can plug the number in the curve and that will give us the threshold thermal flux.

- Similar data can be added to this curves, as the observational data for brush fire (grass ignition)

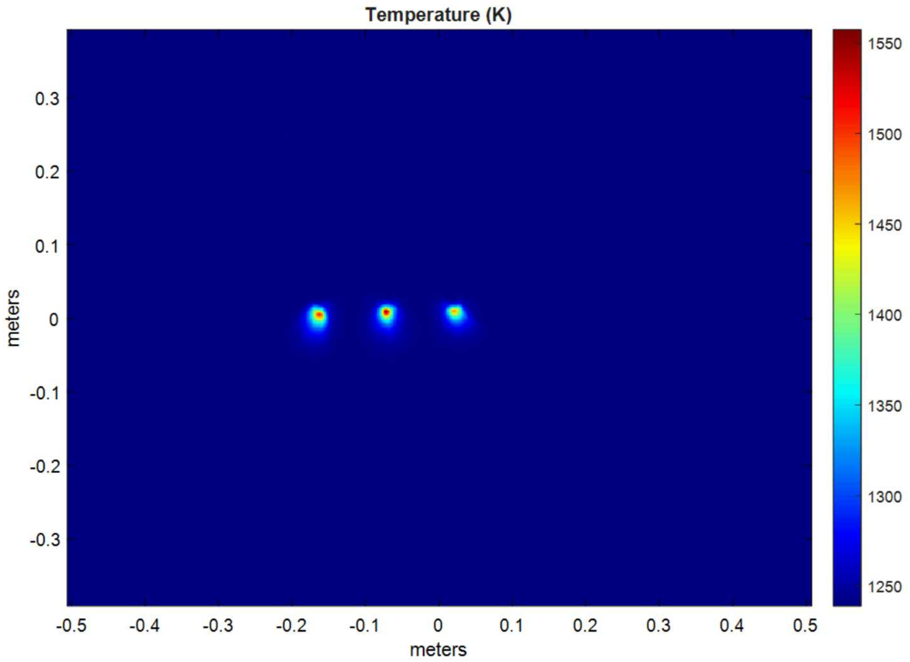
Flux Radiation Calculations

- Flux radiation calculations assume that the arc flash can be approximated to a sphere:
  - Uses averaged infrared data, with a preference for high speed data in this case – See image below.
  - A simpler version of the analysis finds the temperature mean for the flash, its extend, and uses the numbers to simulate a sphere of similar size



$$Ed = \pi L sin^2 \Theta$$

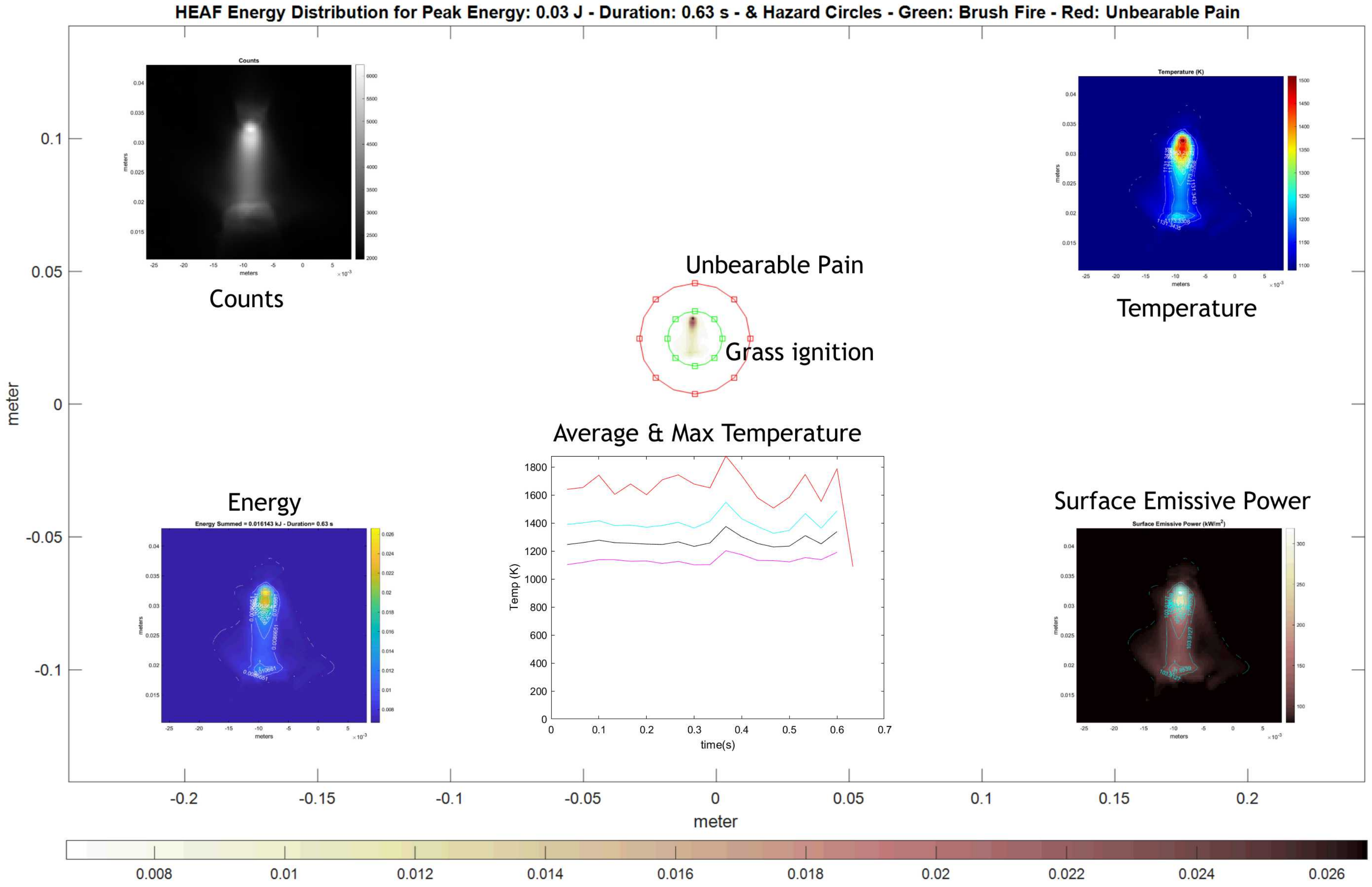
$$sin^2 \Theta = \frac{a^2}{(a+b)^2}$$



  - The code uses radiometric equations for a spherical source with the estimated threshold flux for unbearable pain (Ed), and solves for the distance (b)
  - That distance is the hazard radius
- More sophisticated models can be developed by assuming multiple spheres, calculating the radius for each one. However, this can produce values that are in the noise if distances between the spheres are small compared to obtained radiuses

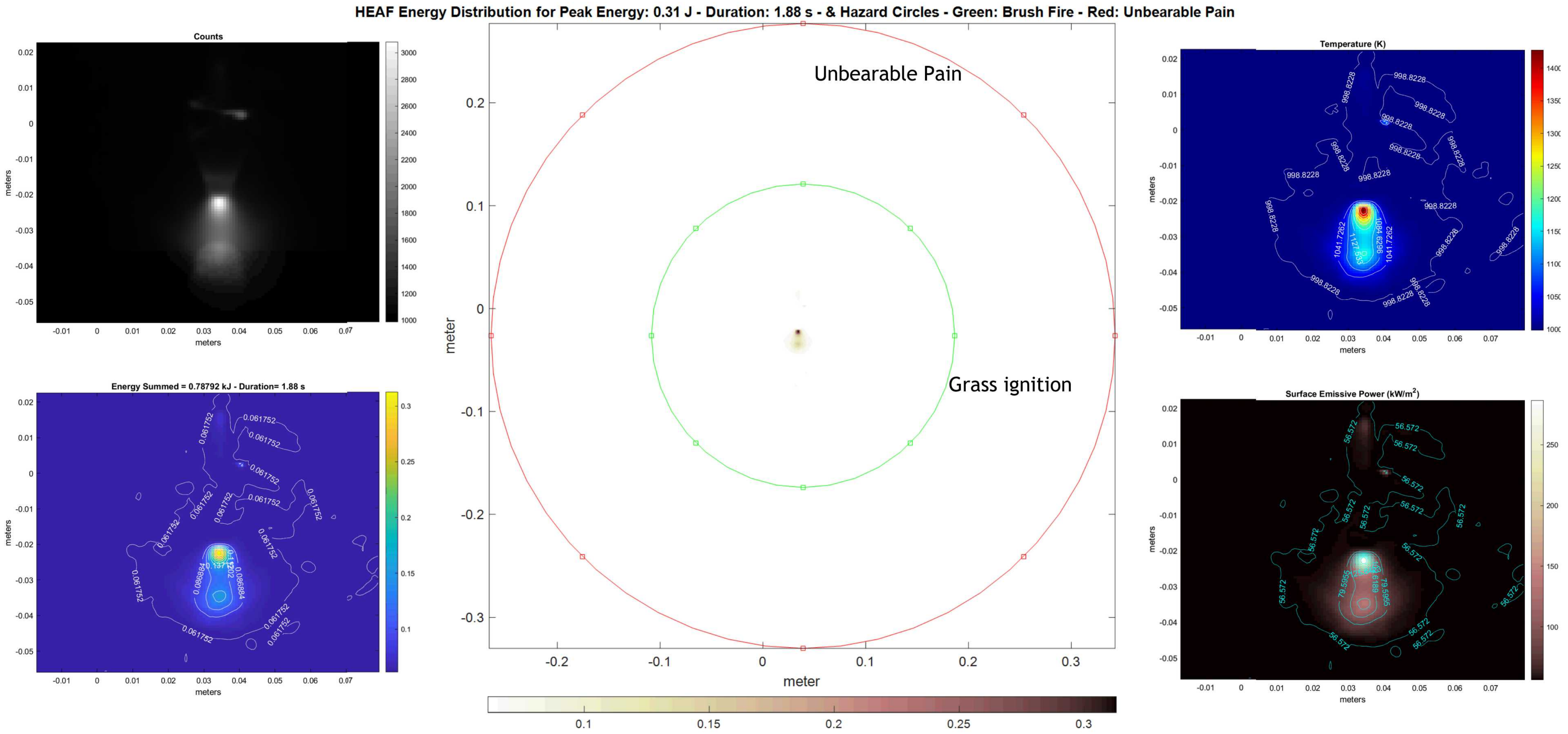
Examples of calculations – Tests at Sandia, NM

Tests performed at Sandia April 15, 2019 – Copper Rods – 12.7 mm apart 300 A – Camera 30fps



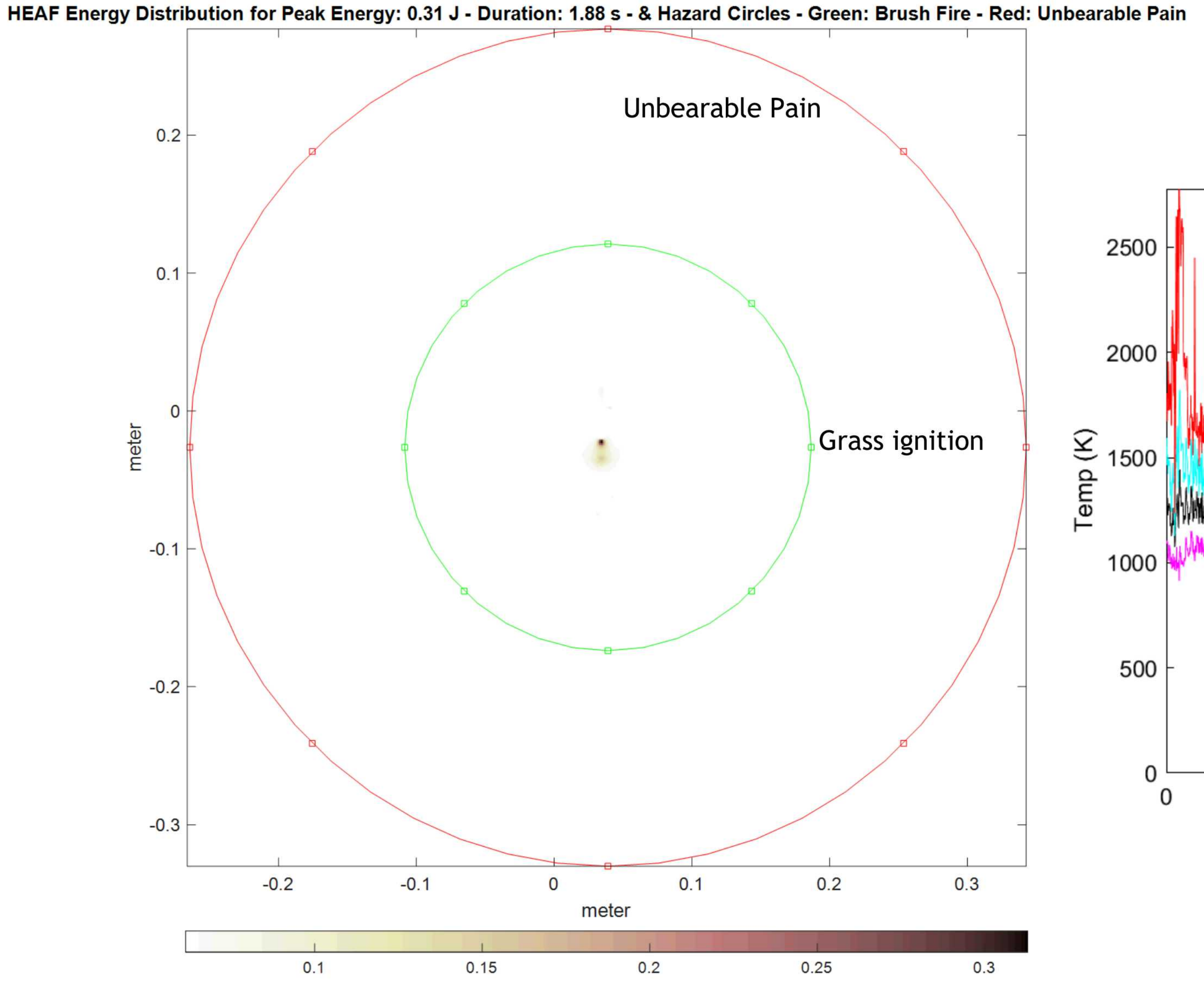
Examples of calculations – DTE Test – pt.1

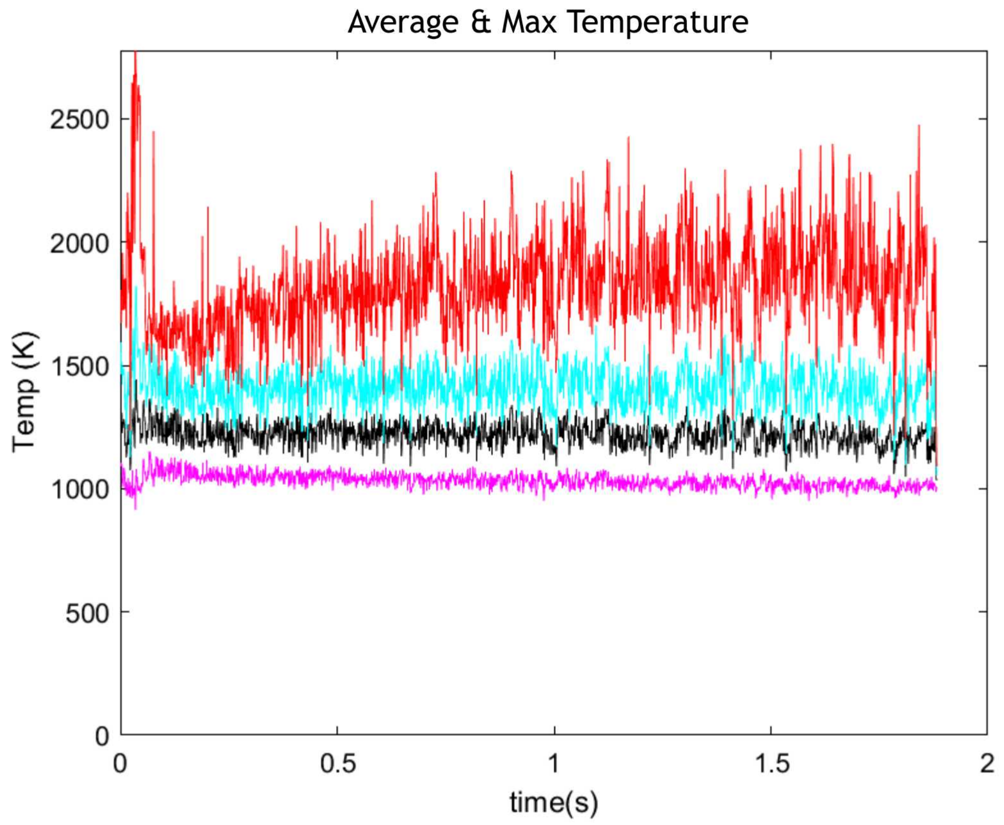
Tests performed at Lapeer, MI July 17, 2019 – Copper Rods – 12.7 mm apart



Examples of calculations – DTE Test – pt.2

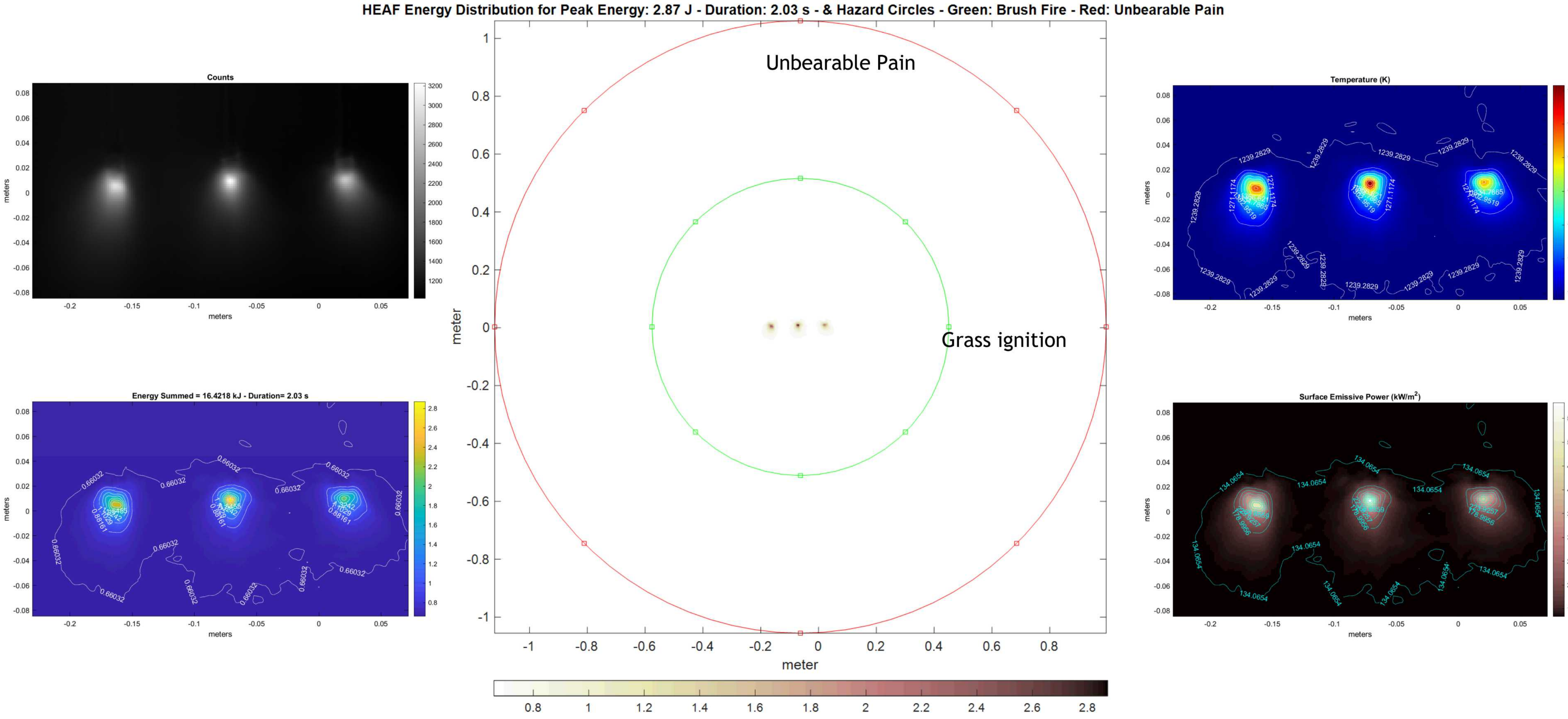
Tests performed at Lapeer, MI July 17, 2019 – Copper Rods – 12.7 mm apart





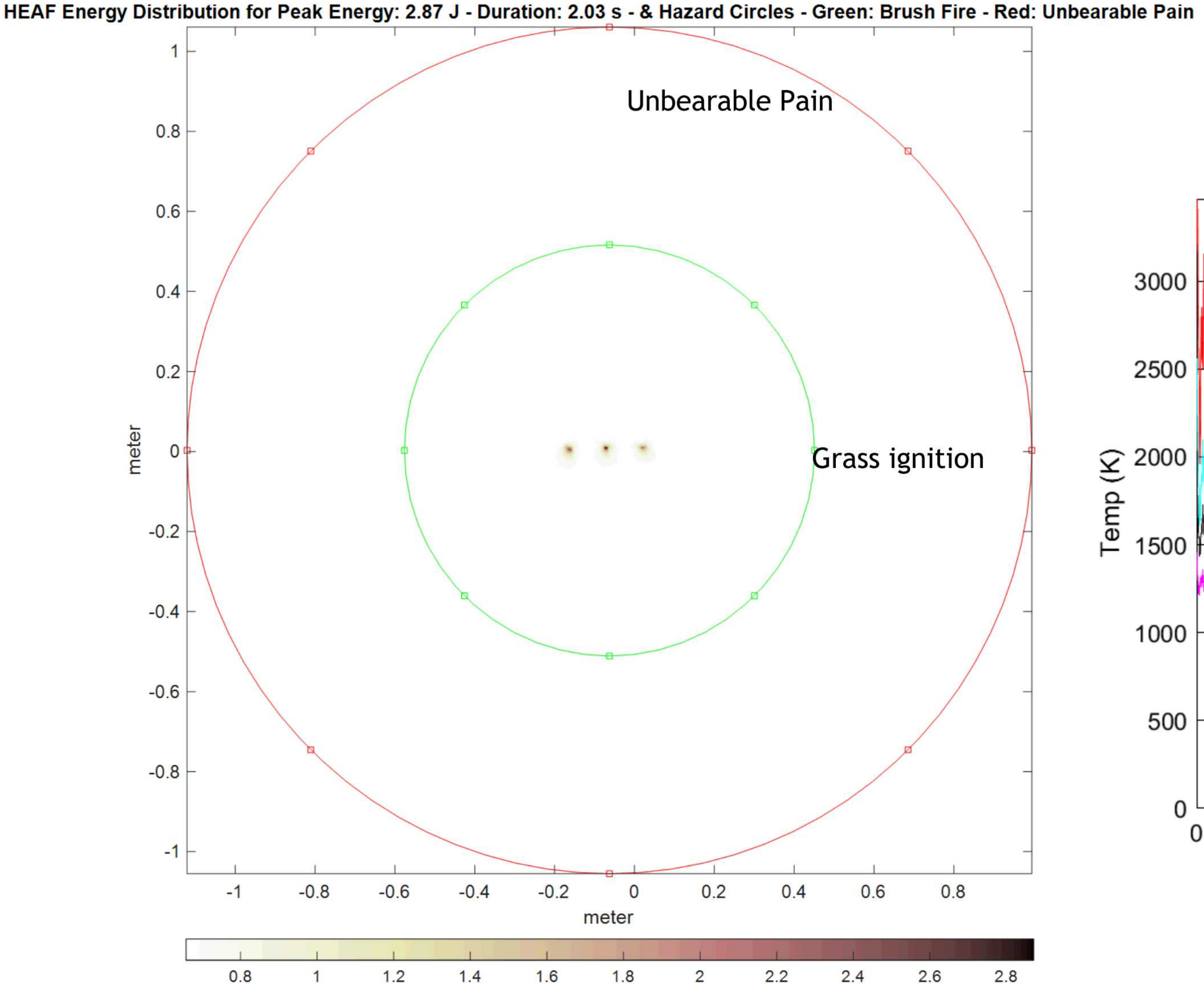
Examples of calculations – Kema Test – pt. I

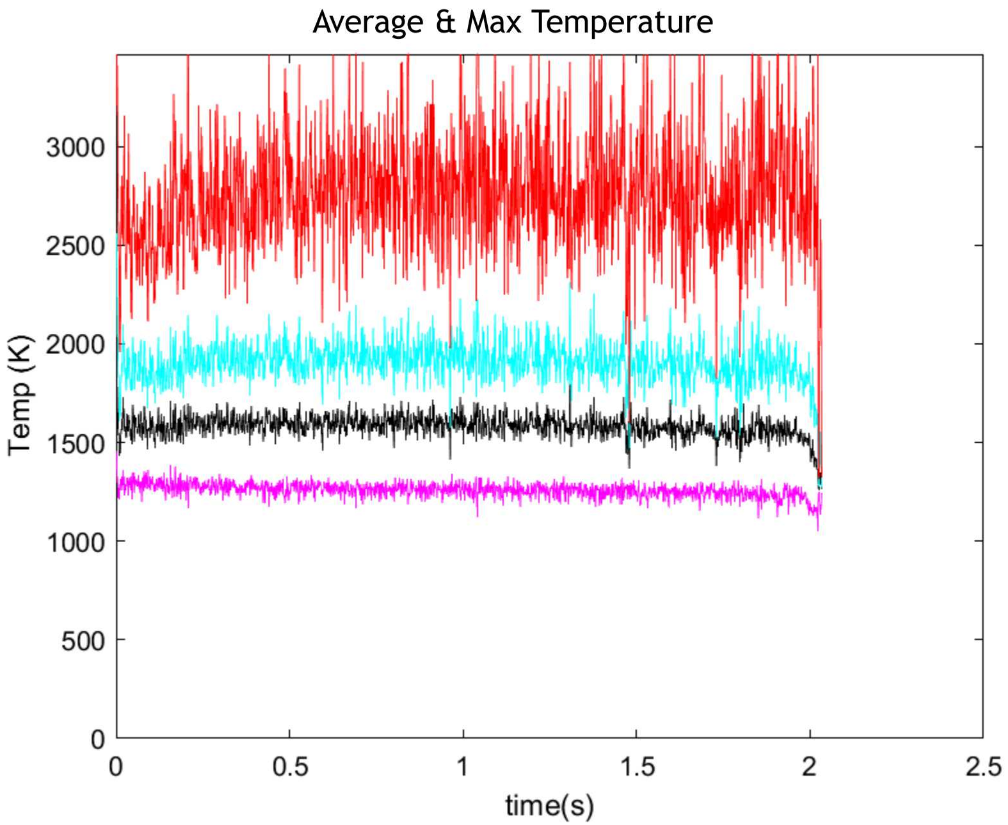
Tests performed at Philadelphia, PA August 20, 2019 – Copper Rods – 3 Parallel – 1kV – 1kA



Examples of calculations – Kema Test – pt.2

Tests performed at Philadelphia, PA August 20, 2019 – Copper Rods – 3 Parallel – 1kV – 1kA





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