COMSOL's Heat Transfer Module and Safe Siting Distances

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INTRODUCTION: Energetic materials are used throughout both private and government industries in manufacturing of small arms ammunition, rockets, air bags, etc. Collections of that material when ignited can pose a risk of serious burns for people in the immediate vicinity. The heat transfer module of COMSOL Multiphysics® was used to simulate barrels of propellant burning to determine the radiative heat flux at various distances. That modeled heat flux result was used to determine a safe distance to prevent second-degree burns. Such an approach can be used to help in issuing guidance for safe distances from Division 1.3 hazardous materials.

STANDARD APPROACH: The Contractor's Safety Manual For Ammunition and Explosives (DOD 4145.26-M) defines the recommended distances for burning propellant (Hazard Division 1.3) that relates the mass to the recommended exclusion distances for safe operations. Unfortunately, those distances relate closely to the fire size and not to the safe distance to prevent second-degree burns.

RECOMMENDED APPROACH: The Heat Transfer Module of COMSOL® can be used to accurately determine the heat flux at distances out away from the flames. At such distances, radiative heat transfer dominates for many scenarios. The radiative heat flux is a function of the gas temperature, composition, gas properties, and emissivities. Critical model parameter values are obtained by matching model output to experimental results of heat flux. Model simulations are then completed for representative conditions to yield the heat flux that can be prohibitively costly to test. That modeled heat flux result can be used to determine a safe distance.

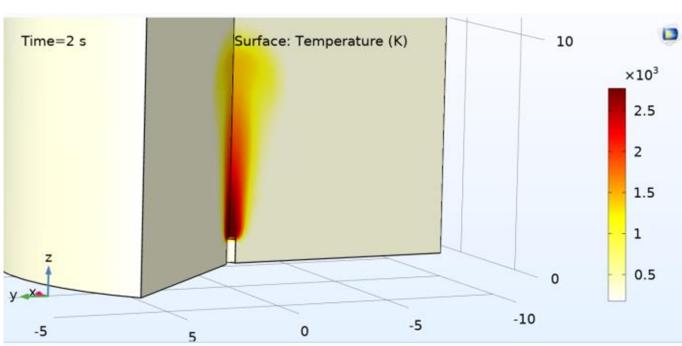

Figure 1. Example radially symmetric simulation of one barrel of burning propellant

RESULTS: An example simulation of a burning barrel of propellant is shown in Figure 1 for a radial symmetric and steady state condition with constant exit gas temperature and gas molar flow rate. Figure 2 shows several different burn scenarios with test data also plotted. There's also an untested condition simulated with seven barrels.

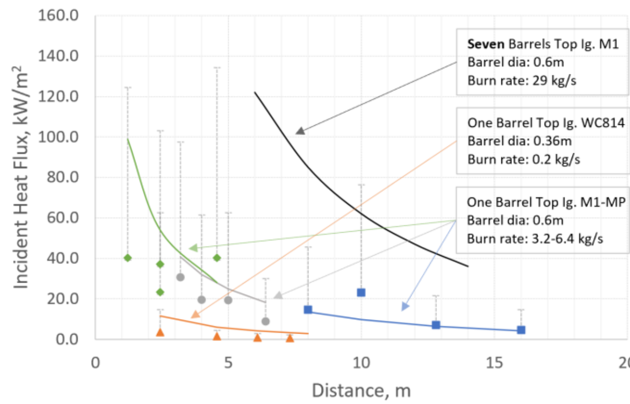

Figure 2. Multiple different top-down burn scenarios with different propellant types showing the heat flux as a function of distance as experimentally measured (points with error bars). Also shown are the COMSOL model results as lines.

CONCLUSIONS: Using the COMOSL model with tuned parameters can yield accurate heat-flux estimates for various propellant burning scenarios that could be encountered in industry. Those estimates can then be used to prevent harm to surrounding personnel. Given an expected burning rate, the safe distance that personnel can be located to prevent second degree burns is plotted in Figure 3 (both experimental and Model results). Large burning rates can be difficult to test while the model can yield accurate estimations.

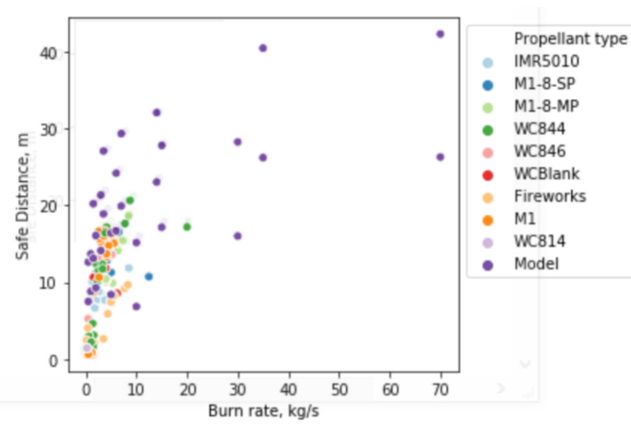

Figure 3. Various propellant top-down burning scenarios with their corresponding safe-distances to prevent second-degree burns.

REFERENCE:

1. J. Edmund Hay and R. W. Watson, Scaling Studies of Thermal Radiation Flux from Burning Propellants, Department of Interior, Bureau of Mines, (1992)