Characterization of Dry Chemical Powders using Reduced-Scale Fire Test Methodologies

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Introduction

The development of new dry chemical fire extinguishing media typically requires considerable qualification work to meet pertinent Underwriters Laboratories (UL) test specifications [1]. This is an expensive and time consuming undertaking. Clearly, it would be desirable for fire extinguisher manufacturers to be able to evaluate potential alternative dry chemical candidates on a smaller but realistic scale, thereby allowing research and development to be conducted rapidly on an economically attractive basis.

In order to ensure experimental repeatability and determine the intrinsic efficiency of each powder as accurately as possible, it is desirable to eliminate sensitivity to operator skill or technique, which plays a significant role in full-scale testing of fire extinguishers. This could be accomplished in at least one way by designing a fixed discharge system that would function reliably and independently of all but the most fundamental operator input.

Scaling Approach

Reduced-scale class B fire tests have been designed with the intention of preserving as many of the essential characteristics of full-size UL fires as possible. Visualization of dry chemical powder discharge patterns was carried out to aid refinement of the geometry of the fire tests.

The dimensions of the reduced-scale class B fire test were selected such that the turbulent combustion and radiative heat transfer mechanisms observed in large fires were essentially preserved [2]. Limited use was made of dimensionless scaling factors, because for some aspects of the combustion process, strict preservation of the dimensionless factors such as Froude number[i] (an approach successfully used to scale down sprinklered fires) would have required changing the fuel from heptane [3]. This was considered undesirable, because the powders extinguish the flame via a combination of chemical and physical effects that may be fuel dependent, and in any case, UL specifies heptane as the class B fuel.

Experimental

All fire tests were performed inside a ventilated steel enclosure. The general experimental arrangement consisted of a fire extinguisher mounted at a fixed distance from the fire, with the nozzle held at a constant angle of inclination to the scaled-down pan.

Two different pans were used for class B tests, denoted 1 and 2. Pan 2 had twice the diameter of pan 1 and therefore four times the surface area. The horizontal distance between the plane of the nozzle and the center of the pan (denoted L in Figure 1 below) was adjusted in either case, so that the central axis of the powder plume was directed to the center of the pan.

Commercial grade heptane was floated on water in the pans with the relative quantities measured by depth (following the established practice of UL 711). The heptane was ignited and combustion was allowed to become fully established before the extinguisher was activated. The mass of powder required to extinguish the fire was noted in each case and the average from at least 6 successful tests was computed.

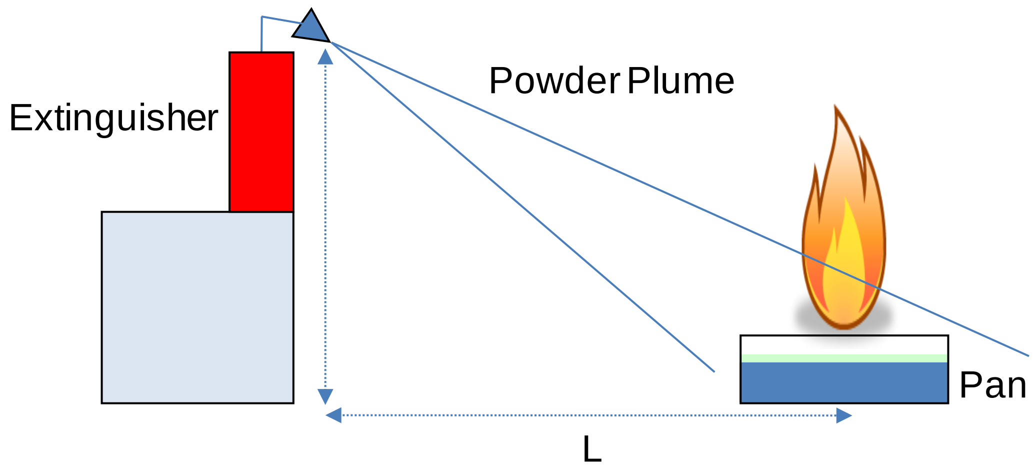

Figure 1. Test Configuration for Class B fires

Results

Sample class B fire extinguishing data are presented in Figure 2. For clarity, error bars representing the standard deviation are plotted for Kidde ABC powder data only. Similar statistical variation was observed for the BC powders.

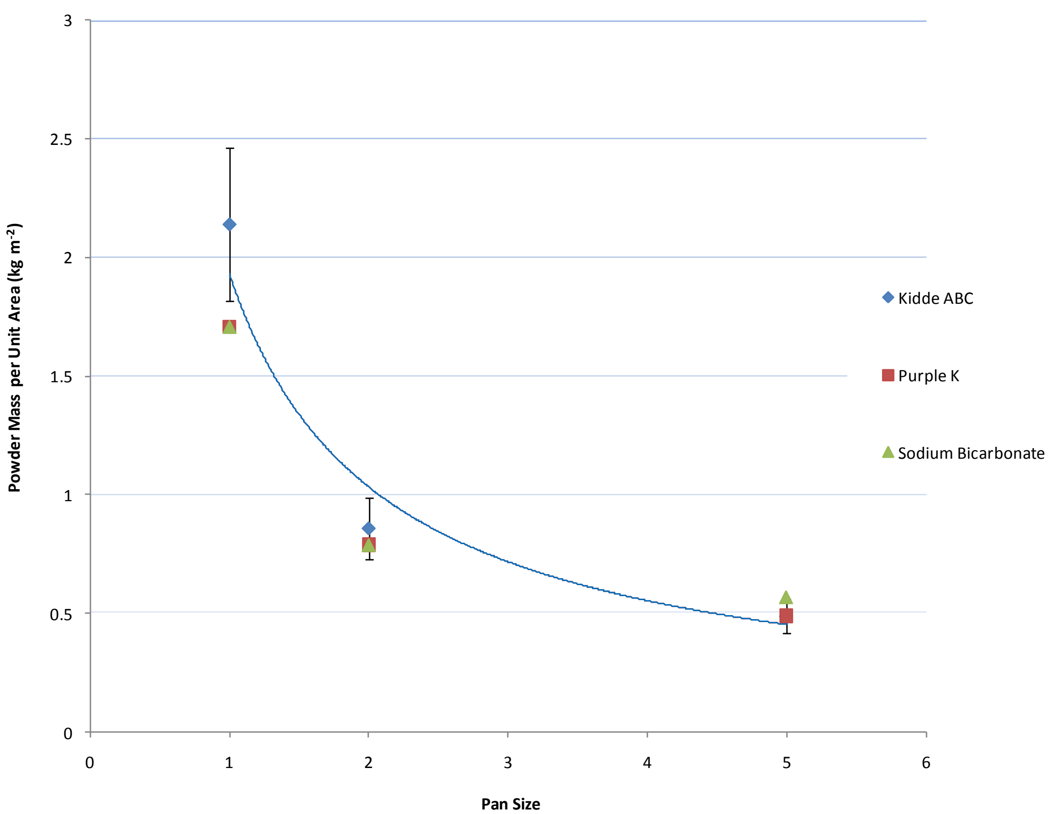

Figure 2. Class B Fire Extinguishing Data

Results obtained during this study indicated that the reduced-scale class B tests did not differentiate between the powders for a given pan size, which is in fact consistent with data on commercial extinguishers holding the UL 10B rating. A statistically significant difference in the average mass of a given powder required to extinguish the fire in either pan 1 or 2 was observed, however.

Conclusions

Subject to confirmation by further test work, the following preliminary conclusions were drawn from this study:

1. Reduced-scale class B fires have been designed and evaluated, but strict preservation of dimensionless groups describing important fire characteristics, such as Froude number, was found to be impractical for scaling UL fires.
2. The reduced-scale class B fires were designed on the basis of preserving fundamental physical mechanisms pertinent to full-scale UL fires, such as turbulent flow and radiative heat transfer to the fuel (heptane).
3. Pan 2 was found to provide extinguishing mass data with smaller relative errors than for pan 1 and is therefore preferred as a class B fire test article for scaling UL fires.
4. Reduced-scale class B test data did not allow performance differentiation between BC and ABC powders, which is consistent with data for commercial UL 10B rated extinguishers.
5. A non-linear relationship between class B fire size and mass of powder required for extinguishment has been observed. Further data are required to confirm that a valid scaling relationship exists between reduced-scale and UL fires.

References

1. Underwriters Laboratories Standard for Safety for Rating and Fire Testing of fire Extinguishers, UL 711, 7th Edition, December 17, 2004.
2. "Estimating Large Pool Fire Burning Rates", V. Babrauskas, *Fire Technology*, Volume 19, pp 251-261, 1983.
3. "Physical Scaling for Water Mist Fire Suppression – A Design Application" J.G. Quintiere, G-Y Su and N. Schultz, *International Journal on Engineering Performance-Based Fire Codes,* Volume 9, Number 2, pp 87-108, 2007.

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[i] The Froude number is significant in fire scaling because it characterizes the ratio of inertia to buoyancy in the gas flow containing the flame. It is defined thus:

$$F = \frac{u^2 T_\infty}{Lg\Delta T_0}$$

where u is the gas velocity, T_∞ is the ambient temperature, L is a characteristic length, g is acceleration due to gravity and T_0 is a reference value of temperature above ambient. The combustion process is assumed to be controlled by recirculating turbulent mixing of fuel and air, and if the governing equations for flow and energy transfer outside the fire boundary are normalized with gas velocity, temperature gradient and concentration of reaction species, it can be shown that these quantities are functions of the Froude number.

From "Scaling the Interaction of Water Sprays and Flames", G. Heskestad, *Fire Safety Journal*, Volume 37, pp 535-548, 2002.