Review of Blinov and Khudiakov's Paper on "Certain Laws Governing Diffusive Burning of Liquids" by Hoyt C. Hottel

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IN 1959, MY freshman year at Massachusetts Institute of Technology, Hoyt Clarke Hottel, a Professor in MIT's Department of Chemical Engineering published an article in Fire Research Abstracts and Reviews [1]. This paper reviews work that had been published two years earlier by Blinov and Khudiakov [2], two researchers from the Soviet Academy of Sciences in Moscow. The Blinov and Khudiakov paper describes the burning of gasoline-like liquids in pans ranging in size from a fraction of a centimeter up to nearly 30 meters in diameter. Professor Hottel's review is not simply a discussion of Blinov and Khudiakov's results, which are presented in tables in the original paper, but is really a thorough analysis of flame heat transfer phenomena associated with the burning of liquid pool fires. Not much more

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is known today about how burning rates in pool fires are influenced by flame heat transfer.

Professor Hottel spent a remarkable 76 years working at MIT [3], as Director of the Fuels Research Laboratory for 35 years, as a full Professor for 28 years and as Chair of the MIT Research Committee on Solar Energy for 27 years. While directing the Godfrey L. Cabot solar energy R&D program for some 30 years at MIT, Professor Hottel and associates were the first to develop accurate analytical models for flat-plate solar heat collectors. This and related accomplishments resulted in the establishment of the annual Hoyt Clarke Hottel Award that is presented by the American Solar Energy Society [4].

I didn't meet Professor Hottel during my 10 years in the Mechanical Engineering Department at MIT but was fortunate to see him at meetings during my first few years at Factory Mutual Research. What I remember most clearly about Professor Hottel were his comments, spoken with a serious demeanor and authority, about having "done all of that years ago" in connection with whatever research results were being discussed by us fire science novices.

Professor Hottel was indeed a charismatic individual who was a fire research pioneer by virtue of two 1949 papers on flame behavior in laminar [5] and turbulent [6] gas jets. Professor Hottel also chaired the National Academy of Sciences Fire Research Committee from 1956 until 1967. This committee studied tactics for fighting large fires, including firestorms in urban areas.

In his review of the Blinov and Khudiakov work, Professor Hottel produced a plot of the tabulated measurements that stands to this day as a graphic explanation to fire protection engineers of how physical dimensions, or scale-effects, can change fire behavior. This plot and Hottel's accompanying flame heat transfer analysis shows why laboratory fire simulations can easily lead to erroneous conclusions. Thermal radiation heat transfer dominates real fires, not the pan conduction effects and convective heat transfer that characterize smaller scale laboratory fires. The famous Hottel plot describing pool fire burning rates and flame heights still appears, unchanged, in the chapter on Fire Hazard Calculations for Large Open Hydrocarbon Fires in the SFPE Handbook [7]. Here it is shown with graphic clarity that pool fire burning rates per unit surface area tend to be a relatively constant, radiation-controlled value for pan diameters greater than about one meter, independent of whether the flammable liquid is gasoline, kerosene, diesel oil or solar oil.

Possibly stimulated by Hottel's article, Burgess et al. [8] and coworkers at the U.S. Bureau of Mines a few years later developed a very practical correlation for liquid pool fire burning rates in the radiation dominated regime. This correlation shows that burning rates depend on the ratio of the fuel heat of combustion to the heat required to raise the fuel temperature to the boiling point and then vaporize it. However, the heat transfer formulas proposed by Hottel remained highly relevant. A 1967 literature survey of all the important contemporary studies, in a paper by Blackshear and Murty [9], concludes "the burning of liquid fuel on surfaces and in pans can be correlated by using the simple theory of Hottel for individual fuel elements."

Hottel's explanation of how geometric scale and different heat transfer modes affect fire behavior constitute probably the two most important scientific concepts that have been developed for fire safety engineering during the last 30 or 40 years. Ironically, Blinov and Khudiakov published a complete report [10] covering their years of work on flammable liquid fires about four years after their original, 1957 paper. In this report, there are plots and a heat transfer analysis very similar to what Hottel had produced for his 1959 review, which obviously had made an impression on the original authors.

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