NISTIR 6527

Measurement Needs for Fire Safety: Proceedings of an International Workshop

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U.S. Department of Commerce
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Technology Administration
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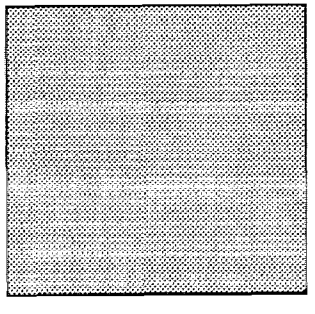
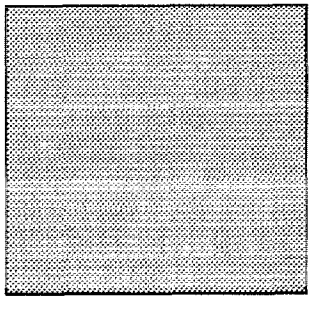
Burning item sub-models



Vytenis Babrauskas
Fire Science and Technology Inc.
Issaquah, WA



Presentation organized into 2 groups

(1) Combustibles for which some sort of model or formula is available

(2) Combustibles where example HRR data exist, but no predictive formula is available

Combustibles for which some sort of model or formula is available

- Gas jets
- Pools, liquid or plastic
- Wood cribs
- Upholstered furniture
- Wall/ceiling linings
- Electric cable trays
- Christmas trees
- Wood pallets

Burning items based on theory

- Gas jets
  - Trivial case
- Liquid pools
  - Principle: HRR controlled by incident heat flux and heat of vaporization
  - First application: COMPF2 (1979)
  - Great deal of research by Koseki, Hamins, Putorti, etc.
  - Surprisingly, this "old technology" is not included in most fire models.

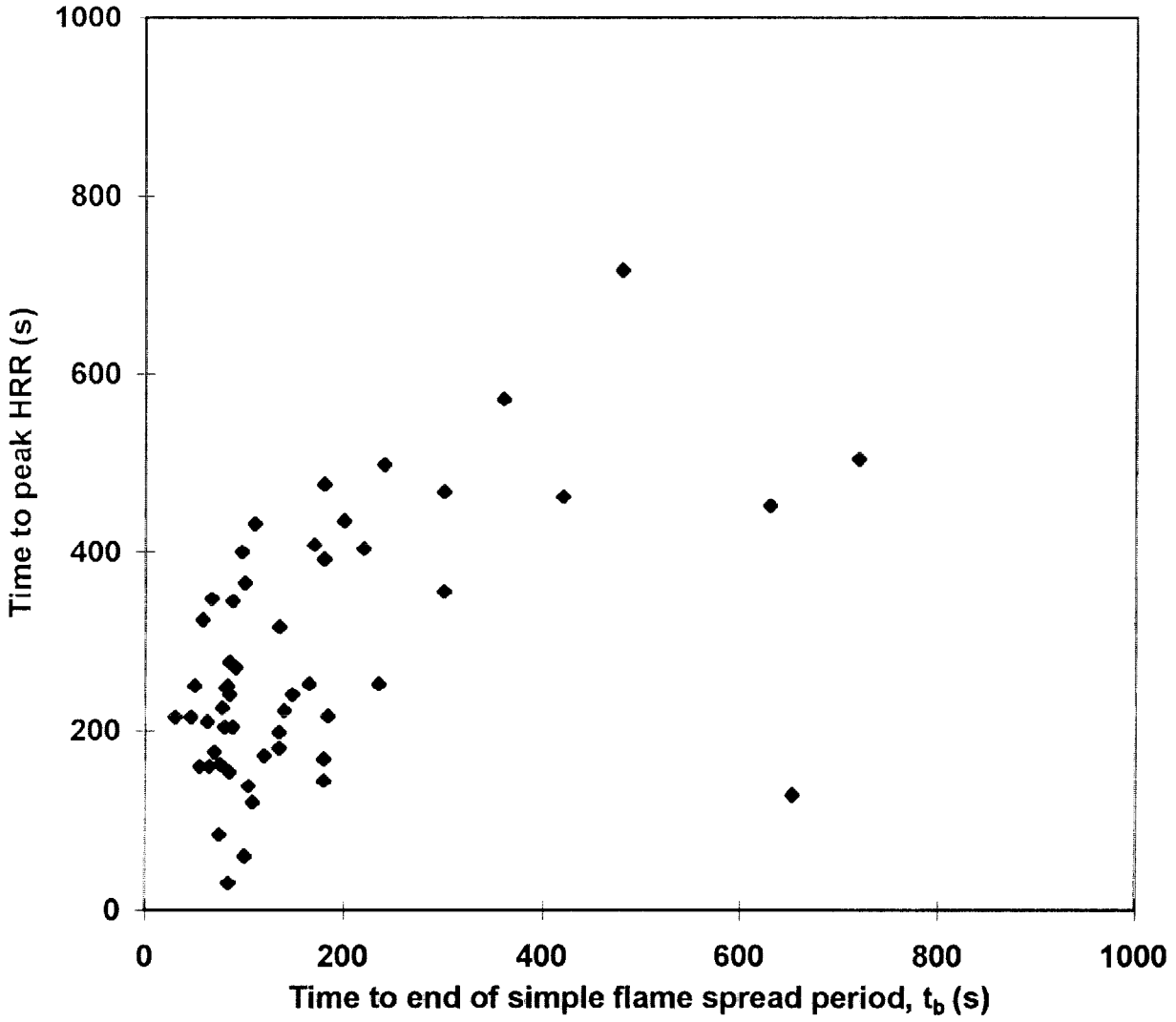
Wood cribs

- A rather special case--correlations are empirical, but assisted by a number of theoretical concepts.
- First studied in Japan by Kawagoe, et al. in the 1960s
- Later studies at Lund, FRS, NIST, FRI, etc.
- Summary equations published by Babrauskas in 1981.
- No significant progress since then.
- Plastic cribs
  - Have been studied by several investigators, but not enough data for good prediction.

Upholstered furniture & mattresses

- Of profound interest from the point of view of fire deaths.
- The need to study furniture flammability was the reason that the Cone Calorimeter and the Furniture calorimeter were invented.
- Empirical data have been collected since 1981 at NIST, Cal. BHF, FRS, CBUF, etc.
- Modeling problem is unfortunately exceedingly complicated.

Problems in modeling furniture fires



Problems in modeling furniture fires--cont'd

- Simple flame spread theory cannot hope to predict actual burning surface area
- Delamination, falldown, two-sided burning, and pool burning are phenomena causing problems
- FRS studies showed that pool fire under the chair sometimes contributes 50% of total HRR (but sometimes 0).

Modeling furniture fires--cont'd

- First modeling attempt: Babrauskas (1983)
  - based on a simple correlation, including specimen mass, bench-scale HRR, etc.
- Prediction of Cal. TB 133 furniture: Parker (1990)
  - limited to single-seat institutional seating
- CBUF: ambitious furniture research program (1995)
  - produced 3 furniture HRR sub-models

CBUF furniture models

- Model I
  - correlations-based, but larger data set than original NIST study; more sophisticated correlation
- Model II
  - based on a convolution integral of bench-scale HRR with instantaneous burning area
  - burning area expressions were derived by empirical de-convolution.
  - reasonable physics, but very few cases studied.

CBUF furniture models--cont'd

- Model III
  - describes mattresses only
  - based on an adaptation of upward flame spread theory
  - is the most "physics-based" furniture model so far
  - but, very few trials, not likely to be adaptable to upholstered chairs, sofas
- Not modeled
  - chairs with hard-plastic shells (not enough data) … but they are important in offices.

Wall/ceiling linings

- Correlational approach: Babrauskas (1984)
  - flashover time proportional to:
    (ignition time)/(peak HRR)
- Convolution method: Wickström and Göransson (1987)
  - originally limited to ISO 9705 room
  - a reasonable balance between physics and empiricism
  - later (1993) extended to a 'huge-scale' test room of 6.75 x 9.0 x 4.9 m.

Wall/ceiling linings--cont'd

  - Wickström / Göransson model has been incorporated into the BRANZFIRE model
  - extensions to other room sizes not validated
- Quintiere/Cleary model (1991)
- Karlsson model (1992)
- Several authors have also proposed using flame spread algorithms within CFD codes
  - Opstad (1995)
  - Zhenghua / Holmstedt (1996)

Electric cable trays

- Lee (1985) developed a correlational procedure based on the data of Tewarson and Sumitra
- A very limited correlation was developed by Przybyla and Gandhi (1992)
- FIPEC is going to present a predictive method based on on upward flame spread model (2000)

Christmas trees

- A correlation has been developed for the peak HRR of Christmas trees (Douglas fir), based on moisture content and specimen mass
- Not previously published, will be included in 3rd edition of SFPE Handbook.

Wood pallets

- A simple correlation is available for stacks of pallets, based on pallet height and wood moisture content (prepared originally for 1st edition of SFPE Handbook).

The above are all of the "models" of HRR that can be found in the literature

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Now, simple data compilations can be considered

HRR data to be provided in 3rd edition of SFPE Handbook

- Greatly expanded set of empirical data
  - Artificial plants
  - Carpets
  - Clothing items
  - Coffee makers
  - Curtains
  - Dressers
  - Industrial stored commodities
  - Kiosks

HRR data to be provided in 3rd edition of SFPE Handbook--cont'd

- Office work stations
- Pillows
- Pipe insulation
- Television sets
- Transport vehicles and components
- Trash bags and containers
- Windows, plastic

Conclusions 1/2

- NONE of the combustibles have a satisfactorily complete and well-validated sub-model
- Wall/ceiling linings would appear to be the best candidate for a state-of-the-art effort at producing a flexible, yet tractable sub-model.
- Interactions of burning items are extremely poorly known.

Conclusions 2/2

- It is dismaying that no "meta-model" exists for furnished rooms.
  - Insufficient data (and no modelling efforts) are available to characterize heavily furnished rooms.
  - If a room contains a wide array of combustibles, it should be possible to compute ***some*** useful fire characteristics, even if there is much less innate physics than in single-item studies.