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Author: Arnaud Trouve', Thomas Minnich

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Author(s): Dr. Arnaud Trouve'
Thomas E. Minnich

Preface: This project was highly technical and included a large amount of research. It also demanded an organization of materials.

Dr. Trouve' monitored the work of graduate student Meghan McKeever during the entire project to meet the NIJ outline requirements.

Thomas E. Minnich
Technical Manager, NCFS

Abstract

Under a grant from the National Institute of Justice (NIJ) that awarded in February 2007, the University of Maryland's Fire Protection Engineering Department worked in conjunction with the National Center for Forensic Science (NCFS) of the University of Central Florida UCF) to develop a centralized Thermal Properties Database. The goal and design of the centralized database was to streamline the process required to determine thermal properties and burning behavior of materials and/or objects. The "Thermal Properties Database" was developed in two components: first, a material property component and secondly an object component. This database is beneficial to all fire communities (*i.e.* forensic scientists, fire investigators, fire protection engineers, etc.).

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Executive Summary

An extended Thermal Properties Database that contains information on the flammability of materials and/or objects relevant to fire safety problems was generated by performing a literature review and querying Fire Research Laboratories around the World. The extended Thermal Properties Database features two components: a material property component and an object property component. The material property component (Thermal Properties Database) contains information on thermal properties, ignition temperatures, critical heat flux at ignition for different representative materials (metals, plastics, woods, and miscellaneous) and is populated by cone calorimeter test data in which fuel sources are described using a material-science-based microscopic view point. The object property component (Burning Item Database) contains information on post-ignition fuel mass loss rates, heats of gasification, heats of combustion for different representative flammable objects (beds, chairs, curtains/draperies, electronics, furniture, multiple items, sofas, and miscellaneous) and is populated by furniture calorimeter test data in which fuel sources are described using an engineering-based macroscopic view point. Over 500 entries populate the Burning Item Database, including generic pieces of furniture, pieces of equipment, and miscellaneous items that determine the fuel load of a representative compartment. Each entry gives descriptive details about the item and links to published sources and available data. The Thermal Properties Database has been web-formatted and published online (*http://www.FireBID.umd.edu*).

The extended Thermal Properties Database is a stand-alone tool to be used for hand calculations and analysis by fire investigators, forensic scientists, and fire safety engineers and researchers. It also provides valuable input data for computer-based fire modeling. This last point was demonstrated by performing sample simulations of simple compartment fire configurations using the Burning Item Database (BID) and the Fire Dynamics Simulator (FDS) developed by the National Institute of Standards and Technology (NIST). The study included: the development of a new thermal-feedback-sensitive, BID-based treatment of fuel sources; the integration of that model into FDS; and a validation study based on detailed comparisons between simulation results and experimental data obtained in a previous study performed at the University of Canterbury in New Zealand. Results were found to be satisfactory for simple fuels (*e.g.* a liquid fuel) but larger discrepancies between FDS results and experimental data were observed for more complex fuels (*e.g.* an upholstered chair). Overall, this preliminary study is encouraging and provides a promising alternative to recent trends in fire models towards comprehensive models based on advanced descriptions of the in-solid heat and mass transfer processes combined with finite rate pyrolysis chemistry. It also provides an illustration of how the Thermal Properties Database and Burning Item Database can be used in computer-based fire modeling applications.

Introduction

<u>Statement of the problem</u>

More and more fire investigators are utilizing a forensic approach to determine origin and cause of fires. Included in this approach is the ever growing use of Fire Modeling. Fire dynamics knowledge is essential when analyzing the results and when supplying **thermal properties** for materials. FDS simulations are very sensitive when it comes to material and thermal properties of the enclosure and fuel source. A slight variation in these properties can alter the results tremendously. Defining these properties accurately can be cumbersome because material and thermal properties are not known for every possible fuel source. For example, defining the material of an upholstered sofa precisely may be difficult because the fabric can be a poly-acrylic cotton blended material. Germane to this approach is an understanding of thermal properties of materials that are involved in fires. Prior to the thermal properties database that was created as a result of this project; investigators had no central reference for the thermal properties data needed. The resulting database has addressed and streamlined the process of obtaining vital information on the thermal properties of known materials involved in fires.

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Statement of hypothesis or rationale for the research

The Thermal Properties Database will be available on the NCFS website for all fire investigators. The resulting database provides a "one stop area" for vital forensic information needed in developing opinions on questions regarding thermal properties of materials. The information is also germane in developing Fire Models using Fluid Dynamic Simulation (FDS) programs.

Methods

Fire Dynamics Simulator (FDS) is widely used in the fire community to simulate and understand in detail enclosure fire dynamics. Fire models require accurate descriptions of the fuel sources to simulate the fire behavior. One approach in FDS is to describe the fuel mass loss rate from furniture calorimeter tests. Unfortunately furniture calorimeter tests do not account for enclosure effects on the fuel sources (*i.e.* the thermal feedback of the smoke layer and the air vitiation). This work explores a simple pyrolysis model that uses furniture calorimeter data and applies a correction to the data to represent enclosure effects. The study includes: (1) the development of a database which compiles furniture calorimeter data, (2) the development of a modified version of FDS that incorporates a simple pyrolysis model and (3) a performance evaluation of the model by detailed comparisons between FDS results and experimental data from two studies performed at the University of Canterbury.

In order to populate the Burning Item Database an extensive literature review was performed. Any source which provided furniture calorimeter results of common household and office items were set aside in order to be compiled into the database. All pertinent information (i.e. material composition, first item ignited, heat release rate and mass loss rate history, and reference, etc.) was documented from the sources and categorized as necessary. This information was then published into a centrally located database online (http://FireBID.umd.edu). Compiling the information at a unique location allows people from all areas of interest (i.e. forensic science, fire protection, etc.) to easily locate information of household / office items which have already been tested.

Creating a database filled with the most valuable thermal property data required an extensive literature review. The main steps of the review were to determine what information was already available publicly, how many other databases were available with thermal property data, and how thermal property data could be determined if needed.

Step one of the literature review required an extensive online search for publicly available sources providing information on calorimeter tests and thermal properties of materials or common everyday objects. Numerous data were found with regards to cone, furniture and room calorimeter tests. Calorimeter tests help to determine the most important factor, heat release rate (HRR) which describes the intensity of the fire. The HRR is the rate of the combustion reactions that produce heat. In these calorimetry tests, the burning rate of the object can also be found simply by measuring the mass loss rate (MLR) of the object throughout the test. Calorimetry tests are separated into two types: full-scale and bench-scale. Full-scale testing allows for the HRR of the object to be measured. There are two types of full-scale testing: furniture and room. The furniture calorimeter test is the easier of the two tests to conduct.

Setup of a Furniture Calorimeter Test (NORDTEST)

Furniture calorimeters, aka open-burning HRR calorimeters, were developed in the 1980s by Babrauskas and colleagues at NIST and by Heskestad at Factory Mutual Research Corporation (5). Basically, the object in question is placed on a scale underneath a properly rated hood. The object is ignited and allowed to burn for the time required by experimentation. The smoke is exhausted through the hood and passes instrumentation which measures the oxygen content in the smoke. The oxygen consumption relationship is used to determine the heat release of the object over time (HRR).

A room calorimeter test uses the same methodology as above but the burning is done in a room mock-up in order to get all effects of the compartment. A room calorimeter test requires construction of a specified room in close proximity to a properly rate hood. The room calorimeter determines the HRR through the same process (oxygen consumption relationship) as the furniture calorimeter. The HRR measured in room calorimeter tests will be much larger than the HRR measured in furniture calorimeter tests because of the enclosure effects on the development of the fire.

A fire in an enclosure develops depending on the enclosure geometry and ventilation and the fuel type, amount and surface area. Development of fires consists of five stages: ignition, growth, flashover, fully developed fire, and decay.

After ignition, the fire spreads and produces an increased amount of energy, toxic and nontoxic gases and solids (soot). An enclosure fire initially develops similarly to the development of a fire in an open environment. In this stage, the enclosure has no effect on the fire and the fire is considered to be fuel controlled.

The growth stage begins when a fire plume develops as the hot gases from the flame rise upward because it is more buoyant than the colder gases in the enclosure. Once the fire plume reaches the ceiling the hot gases will then spread across the ceiling, forming ceiling jets. When the ceiling jets reach the walls, the hot gases are forced downward. These hot gases are still buoyant and travel back towards the fire plume creating a hot layer of gases under the ceiling.

Various studies have shown enclosures are divided into two layers: upper (hot) layer and the lower (cold) layer. The upper layer is a mixture of the combustion products and entrained air, while the lower layer is just air. The air from the lower layer is continuously entrained into the fire plume as the fire grows. The hot layer descends as the fire grows. If vents are present, the hot layer descends to these points and begins to spill outside the enclosure. As the hot layer descends, it also increases in temperature. The heat from this layer is transferred by radiation and convection to the ceiling and walls of the enclosure. The heat from this layer is also transferred to the floor, lower layer and fuel through radiation. Heat is radiated to the fuel from the flame, hot layer and hot boundaries. Increasing the amount of heat transferred to the fuel increases the burning rate of the fuel and the heating of other objects in the enclosure.

Fires in enclosures continue to grow as long as there is fuel to burn and enough oxygen available in the enclosure to allow for complete combustion. If the upper layer reaches an extremely hot temperature, flashover may occur. Flashover (third stage) occurs if all of the combustible materials in the enclosure are ignited, causing a rapid increase in energy release rates.

At the fully developed fire stage, all combustibles are involved in the fire and the flames are extending outside the enclosure openings. The fire reaches the decay stage when there is no more fuel left to burn.

If an enclosure does not have any vents or not enough oxygen, the hot layer will descend to the flame region and starve the fire of oxygen. Although the energy release rate decreases, pyrolysis can still continue causing an abundant amount of unburned gases to collect in the enclosure. If a window or door is suddenly opened in a room where a large amount of unburned gases has collected, backdraft is highly likely.

Bench-scale testing estimates the HRR by testing samples of the object in question. The most common bench-scale testing is the cone calorimeter developed by Babrauskas at NIST.

During the literature review, a handful of databases which had already compiled fire data were found. Although a handful of databases were found, about half of these databases were only discussed in documents and not actually available to the public online. The databases not available online were either still being developed, required a registration fee, or were available only on a computer at the University of Canterbury.

Five open databases were found: 3 with unrestricted access, 1 requiring registration (free), and 1 available after e-mailing requesting permission to access. All of these sources provided furniture and/or room calorimeter data or thermal properties of a material.

The National Institute of Standards and Technology (NIST) provided two databases: FASTD and CFAST. FASTData documents some of the data from cone, furniture and room calorimeter tests conducted at the Building and Fire Research Laboratory. Information given ranged from item tested, location of test, sponsor, date of test, what type of test was conducted, pictures, movies, HRR plots, and smoke extinction plots. For this research the information used from this source was the data from tests run on household/office furniture (i.e. *mattresses, beds, dressers, bookshelves, etc.).* Although this website provided background information on the tests, actual data were not available online. To acquire the actual data the user must purchase a CD which contains the database and all data in a user friendly layout.

CFAST, Consolidated Model of Fire and Smoke Transport, is a computer program used by fire investigators, safety officials, engineers, architects and builders “to simulate the impact of past or potential fires and smoke in a specific building environment”. Information taken from this source corresponds to the thermal property database which provides the thermal conductivity (k), specific heat (Cp), density (!) for common materials used in construction of rooms.

Another publicly available database was created by Stefan Särdqvist, who published his findings. Särdqvist’s report compiled several full scale tests for different items under various conditions (i.e. furniture or room calorimeter tests) from various sources. The report documented the description of the item tested, the testing type, the HRR, production of smoke and generation of CO, as well as the source of the information. Särdqvist created a digital version of his database which has compiled much of the data from these tests. The items in the database range from coffee makers to chairs to vehicles.

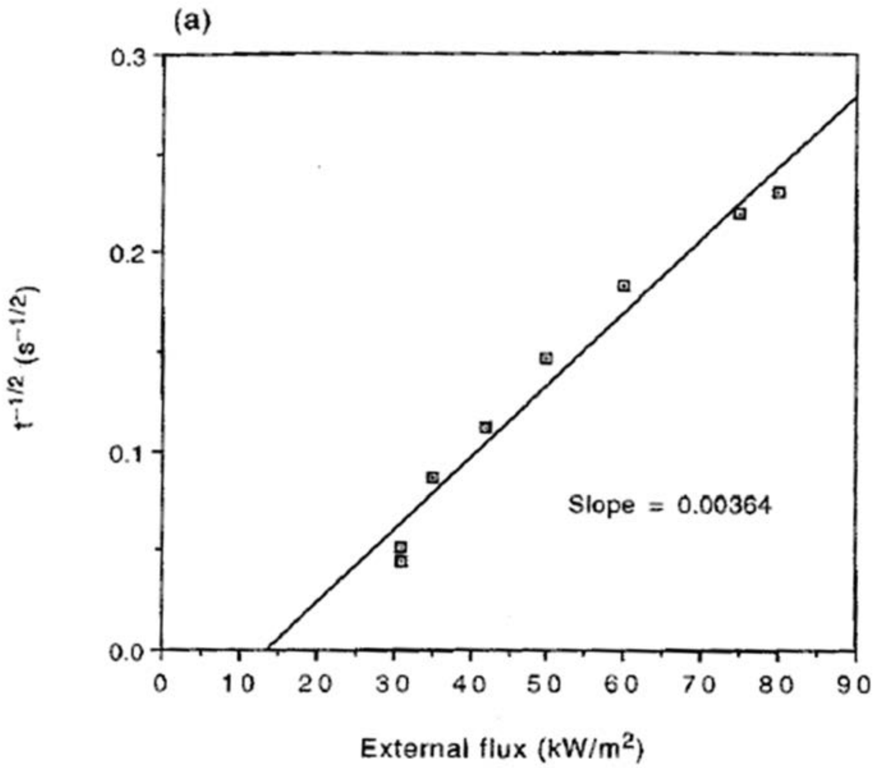
Determining Thermal Properties

Thermal properties of materials are required inputs to calculate fire behavior of an object.

Numerous studies have looked into methods to determine the thermal properties of a material. One of the simplest ways to determine thermal properties is by utilizing cone calorimeter tests. Cone calorimeters tests are much more economical than full scale calorimeter tests because more tests can be run in a shorter time frame, test and human error can be minimized, repeatability tests can be conducted without a large downtime, and the tests are monetarily beneficial. Two methods to determine thermal properties from cone calorimeter data are using simple heat transfer theory such as in the study done by Hopkins and Quintiere and using genetic algorithms.

Utilizing Cone Calorimeter Data with Theory

To determine the thermal properties of a given material, numerous cone calorimeter tests at different heat fluxes ranging from 0 to 90 kW/m2 need to be conducted. (Note: This heat flux range was used by Hopkins and Quintiere in their study, but is only a recommendation not a requirement. As long as there is data from various heat fluxes, the method developed by Hopkins and Quintiere can be utilized.) Prior to testing, the density and thermal diffusivity for the material are assumed to be known. Density is simply obtained from a weight measurement. During testing the mass loss rate, time to ignition and heat flux was documented. After testing a plot of the radiant heat flux versus the square root of the ignition time was created.



Structure of Database / Website

The database began to take form as data from furniture calorimeter tests were compiled from different sources during the literature review. As discussed previously, only furniture calorimeter data for items typically found in households and offices were collected because this information is the one that is relevant to the objective of our DOJ sponsored study.

If an item was tested multiple times using a furniture calorimeter, each of these tests was considered a separate entry. Each source was thoroughly examined and all relevant information was documented. All entries included (if available) a description of the item, the main constituent materials, first material to ignite, material mass fraction, total and combustible weight, maximum HRR, heat of combustion and reference of the test.

Results

Statement of Results

FDS is an engineering tool with many benefits. Unfortunately the current version of FDS is incapable of calculating enclosure effects on the fuel source (i.e. the thermal feedback of the smoke layer and the air vitiation) when furniture calorimeter data are used to describe the fuel mass loss rate. This study considers semi-empirical modeling strategies of the fuel mass loss rate based on furniture calorimeter data and theoretical corrections proposed to account for enclosure effects.

This study was broken down into three parts: (1) the development of a database which compiles furniture calorimeter data, (2) the development of a modified version of FDS (ModFDS) that incorporates Quintiere's semi-empirical pyrolysis model and (3) a detailed comparison between FDS results and experimental data.

The database was developed to centrally locate furniture calorimeter data for common household/office furniture. Centrally locating this database on the internet (http://www.FireBID.umd.edu) allows public easy access. The FireBID database provides valuable information for both the fire protection engineering and fire forensic communities. Data from this database were also used to define a fuel source when running ModFDS.

This research considers a simple pyrolysis model that uses furniture calorimeter data and applies a correction to the data to represent enclosure effects. The model is implemented into a modified version of FDS called ModFDS. ModFDS in theory should be able to take fuel sources defined by furniture calorimeter data and produce results similar to room calorimeter results. ModFDS was test in enclosure simulations with two different fuels: a simple fuel (heptane) and a complex fuel (upholstered chair). The ModFDS results were than compared to the room calorimeter measurements. Results obtained with heptane are encouraging whereas results obtained with upholstered chairs are less satisfactory. Note that the pyrolysis model features adjustable factors (the flame heat flux and the heat of gasification) and results can be improved by careful calibration of these factors.

Tables and Figures

NOTE: Thermal properties which are relevant to fire behavior include the thermal conductivity (k), the mass density (ρ), the specific heat (Cp), and for materials that may undergo thermal degradation (i.e., pyrolysis) the heat of gasification (Lg) and the ignition temperature (Tig).

The below chart has been broken down into four categories according to material types: (1) Metals, (2) Plastics, (3) Woods and (4) Miscellaneous. For each entry, the thermal properties at room temperature and/or ignition temperature have been compiled from various sources. Some materials may have multiple entries due to variations in estimates of thermal properties from one source to another.

Variations across different sources illustrate the difficulty in determining accurate values for k, ρ, Cp, Lg and Tig. For complex materials, these properties are to be viewed as effective properties. In addition, these properties may change significantly with temperature.

Thermal Properties of Materials Used to Construct Common Objects Found in Households and Offices

		Properties at ~300 K					Properties at Tig					
Material	Tig	k	ρ	Cp	(kρCp)To	Lg	k	ρ	Cp	(kρCp) Tig	Lg	Reference
	[K]	[W/m-K]	[kg/m3]	[kJ/kg-K]	[kJ2-s-m-4-K-2]	[MJ/kg]	[W/m-K]	[kg/m3]	[kJ/kg-K]	[kJ2-s-m-4-K-2]	[MJ/kg]	
METALS												

Aluminum		205										13
Aluminum, 6061		167	2700	0.896	404.006							8
Aluminum, 7075		130	2800	0.841	306.124							8
Aluminum, Duralumin (4% Cu 0.5% Mg)	775	177	2770	0.875	429.004							6
Aluminum, Duralumin (4% Cu 0.5% Mg)		164	2787	0.883	403.591							8
Aluminum, Pure	933	237	2702	0.903	578.258							6
Aluminum, Pure		237	2707	0.905	580.611							8
Stainless Steel, AISI 304	1670	14.9	7900	0.477	56.148							6
Stainless Steel, AISI 304		13.8	8000	0.40	44.16							8
Stainless Steel, AISI 316		13.4	8238	0.468	51.662							6
Stainless Steel, AISI 316		13.5	8000	0.46	49.68							8
Stainless Steel, AISI 347		14.2	7978	0.48	54.378							6
Stainless Steel, AISI 347		15.0	8000	0.42	50.4							8
Stainless Steel, AISI 410		25.0	7700	0.46	88.55							8
Steel		50.2										13
Steel, 0.5% C		54.0	7833	0.465	196.687							8
Steel, 1% C		43.0	7801	0.473	158.665							8
Steel, 1.5% C		36.0	7753	0.486	135.646							8
Steel, AISI 1010		63.9	7832	0.434	217.202							6
Steel, AISI 1010		64.0	7830	0.434	217.486							8
Steel, Plain		60.5	7854	0.434	206.222							6
PLASTICS												
Nylon	653		1169			2.4	0.33	1169	2.3	0.87	3.8	5
Polyester	680	0.20	1345	1.15	0.59					1.3		4
Polyethylene	573		955		0.638	2.3	0.64	955	3	1.8	3.6	5
Polyethylene						1.9-2.3					1.9-2.3	11
Polyethylene, Foam						1.55					1.55	4
Polyethylene, HD	653	0.43	959	2.00	0.82	2.3				1.8	2.30	4
Polyethylene, LD	650	0.38	925	1.55	0.54	1.8				1.2	1.80	4

Polyethylene, MD	635	0.40	929	1.70	0.63					1.3		4
Polymethylmethacrylate	453		1190		0.339, 0.365	1.6	0.43	1190	4.1	2.1	2.8	5
Polymethylmethacrylate	578									2.12		9
Polymethylmethacrylate											1.4-1.6	11
Polypropylene	640	0.15	880	1.88	0.25	2.0				0.53	2.00	4
Polypropylene	483	0.38	900	6.30	0.367	2.0		900		2.2	3.1	5
Polypropylene	578									2.15		7
Polypropylene						1.4-2.0					1.4-2	11
Polystyrene	693				1.17							3
Polystyrene	629	0.14	1045	1.25	0.18	1.60				0.39	1.60	4
Polystyrene		0.033				1.7-2.2					1.7-2.2	11,13
Polystyrene Foam	649				0.58	1.3-1.9					1.3-1.9	1,11
Polyurethane		0.02										13
Polyurethane, Flexible	651					1.95					1.95	4
Polyurethane, Rigid	651	0.19	1100	1.76	0.37	3.25				0.78	3.25	4
Polyvinylchloride	688				1.31							2
Polyvinylchloride						3.1					3.1	11
Rigid Polyurethane Foam	643				0.04							1
Rigid Polyurethane Foam						1.2-5.6					1.2-5.6	11
Rubber, Hard		0.16	1190									6
Rubber, Soft		0.13	1100	2.01	0.287							6
SBR	664	0.17	1100	1.88	0.35	2.30				0.78	2.30	4
Teflon		0.35	2200									6
WOODS												
~HARDWOOD~												
Ash		0.15-1.30	740									8
Balsa		0.055	1740									6
Balsa		0.05	100									8
Hardwood		0.16	720	1.255	0.145						3.068	6,4
Mahogany		0.16	700									8
Oak		0.17	545	2.385	0.221							6
oak		0.10-	600	2.39								8

		0.40										
Oven Dry Oak	574									0.45		12
Red Oak						5.1-9.5					5.1-9.5	10
Victorian Ash											2.57	14
Blackbutt											2.54	14
~SOFTWOOD~												
Cypress		0.097	465									6
Douglas Fir						4.6-8.4					4.6-8.4	10
Douglas Fir, Plywood		0.12	550	1.2	0.079							8
Fir		0.11	415	2.72	0.124							6
Fir		0.12	600	2.72	0.196							8
Oven Dry Douglas Fir	623									0.16		7
particle board		0.14	800	1.3	0.146							8
pitch pine		0.14	450									8
Softwood		0.12	510	1.38	0.084					1.80	2.555	6,4
Spruce		0.11	4410									8
White Pine		0.11	435									6
Yellow Pine		0.15	640	2.805	0.269							6
Western Red Cedar											3.27	14
Redwood											3.14	14
Radiata Pine											3.22	14
Douglas Fir											2.64	14
~MISC. WOOD~												
Gypsum / Plaster Board		0.17	800									6
Particleboard, HD		0.17	1000	1.3	0.221							6
Particleboard, LD		0.078	590	1.3	0.060							6
Plywood		0.12	545	1.215	0.079							6
Wood		0.12-0.04										13
MISC.												
Acoustic Tile		0.058	290	1.34	0.023							6
Cotton		0.06	80.0	0.13	0.001							6
Fiberglass		0.04										13
Glass		0.80										13
Glass, Plate		1.40	2225	0.835	2.601							6
Glass, Pyrex		1.40	2500	0.75	2.625							6

Leather		0.159	998									6
Paper		0.18	930	1.34	0.224							6
Paraffin		0.24	900	2.89	0.624							6
Refrigerant, R134a		80.3	1198	1.432	137.758							6
Refrigerant, R22		82.6	1183	1.265	123.610							6
Wool Felt		0.04										13

Tig - Ignition Temperature
(kρCp)To - Thermal Inertia at Room Temperature, To. Use typical values of k, ρ, Cp.
(kρCp)Tig - Thermal Inertia at Ignition Temperature, Tig. (See Refs. 4, 5 or 10 to determine method used.)
Lg - Heat of Gasification. Measured thru experimentation. Lg is the reciprocal of the slope of the mass loss rate per unit surface area plotted versus external heat flux.

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Conclusions

<u>Discussion of findings</u>

The resulting database has resulted in allowing investigators the opportunity to get important thermal properties data needed for the FDS fire modeling software. This database provides a needed tool for the investigators when utilizing the fire modeling software to assist in their investigations.

<u>Implications for policy and practice</u>

FDS is an engineering tool with many benefits. Unfortunately the current version of FDS is incapable of calculating enclosure effects on the fuel source (i.e. the thermal feedback of the smoke layer and the air vitiation) when furniture calorimeter data are used to describe the fuel mass loss rate. This study considers semi-empirical modeling strategies of the fuel mass loss rate based on furniture calorimeter data and theoretical corrections proposed to account for enclosure effects.

Implications for further research

This study was broken down into three parts: (1) the development of a database which compiles furniture calorimeter data, (2) the development of a modified version of FDS (ModFDS) that incorporates Quintiere's semiempirical pyrolysis model and (3) a detailed comparison between FDS results and experimental data. The database was developed to centrally locate furniture calorimeter data for common household/office furniture. Centrally locating this database on the internet (http://www.FireBID.umd.edu) allows public easy access. The FireBID database provides valuable information for both the fire protection engineering and fire forensic communities. Data from this database were also used to define a fuel source when running ModFDS. This research considers a simple pyrolysis model that uses furniture calorimeter data and applies a correction to the data to represent enclosure effects. The model is implemented into a modified version of FDS called ModFDS. ModFDS in theory should be able to take fuel sources defined by furniture calorimeter data and produce results similar to room calorimeter results. ModFDS was test in enclosure simulations with two different fuels: a simple fuel (heptane) and a complex fuel (upholstered chair). The ModFDS results were than compared to the room calorimeter measurements. Results 95 obtained with heptane are encouraging whereas results obtained with upholstered chairs are less satisfactory. Note that the pyrolysis model features adjustable factors (the flame heat flux and the heat of gasification) and results can be improved by careful calibration of these factors.

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References

The thesis "Simulating the Fuel Mass Loss Rate in Fire Dynamics Simulator (FDS) Using a New Furniture Calorimeter Database" is a detailed discussion of this project and was authored by Meghan McKeever, Graduate Student at the University of Maryland. It can be viewed in its entirety by accessing the following site: http://hdl.handle.net/1903/10896.

Dissemination of Research Findings

The project will be discussed in an article to be written for the International Association of Arson Investigators. The organization has over 7,000 members who will have access to the article and the thermal properties database. In addition, organizations such as the International Association of Arson Investigators (IAAI), the National Association of Fire Investigators (NAFI) and state fire organizations' newsletters will have articles submitted for printing detailing the research findings.