

“READY-TO-USE” BUILDING LAYOUTS AND COMBUSTIBLE PACKAGES FOR 3-D FIRE SIMULATIONS^(a)

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ABSTRACT

In recent years, complex 3-D computational fire effects models have been widely used by fire protection engineers to simulate the consequences of fire and to assess effectiveness of fire mitigation options. This has happened in part because these tools have become increasingly user friendly. However, it may not always be appropriate to use a complex model just because it is available. In addition, the use of these complex tools requires considerable time, both for users to create input data files and analyze the results, and for computers to produce the simulations. With respect to input files, independent of the description of the initial design-basis fire itself, information and data are lacking about the way the building itself should be described as input data, the degree of detail that is necessary in order to capture the elements that affect the validation of the simulation, and how to optimize mesh size so that critical elements can be properly incorporated without resulting in a prohibitively lengthy calculation time. In order to begin addressing these issues, this project aims to provide guidance on how to select the right type of tool to fit the engineering application, to collect and make available to the entire fire community, representative building layouts for common occupancy groups, such as schools, offices in high-rise buildings, and hospitals, which can form a common basis for estimating, assessing and verifying building-related model parameters, and to collect and make available a set of ‘combustible packages’ representing 3-D objects such as chairs, couches, and beds, which contain heat release rate, chemical reaction, and toxicity properties needed for the simulations. Together, the tool selection guidance, building configurations and combustible packages will help fire protection engineers become both more efficient and effective in applying the best tools for the application at hand.

INTRODUCTION

Within the performance-based fire protection design framework, tools are used in order to estimate the consequences of fire design scenarios, upon which different fire protection trial designs are evaluated.

A fire scenario describes the evolution with time of the fire, from its ignition to its extinguishment. Not only fire is a threat to the building occupants, but also to the building itself, to its contents and to its own structure. Life safety is a common objective for any built environment and concerning fire hazard, it is essential to evaluate the consequences of the fire in terms of heat effects (temperature and thermal dose) as well as in terms of toxicity and visibility loss which can prevent occupants from finding their way to a safe place so they subsequently succumb to untenable heat and toxic conditions. In order to conduct this analysis, a fire design scenario shall contain information necessary to evaluate the heat released during the fire and also fire effluent productions. This information is then added to the information related to the description of the built environment and incorporated, as user input, to fire effects tools. When selecting appropriate tools for analysis, several factors need to be considered.

Different levels of complexity

The Society of Fire Protection Engineers (SFPE, 2011) defines the three following types of fire effects tools, based upon their levels of complexity:

- algebraic models, which include empirical or analytical equations to describe localized phenomena such as the plume region (temperature and velocity), the ceiling jet, and smoke filling in an enclosed space;
- zone or lumped parameter models, which divide spaces into control volumes where the quantities are spatially homogeneous (and which often include add-on sub-models dealing with particular aspects of the fire description);
- Computational Fluid Dynamics (CFD) models, which can calculate flows through complex geometries by dividing the considered space in relatively small elements where a set of governing equations is numerically solved.

Hybrid tools combining a zone model with a CFD model, a fire effects models with a HVAC network model may also be considered when assessing fire consequences.

Understanding and recognizing the differences in level of complexity and outcomes delivered is the first step in matching tools to applications.

Different uses have different constraints

The next step in selecting a tool is to understand issues associated with objectives and constraints on the project, such as time, resources, and level of analysis required. At the start of a complex project in the consulting environment, for example, fire protection engineers (FPEs) are often asked to provide ideas of the possible fire protection measures, even when the project itself is not well defined. At this stage, the level of analysis required will be driven by the level of complexity needed given the scarcity of input data describing the project (i.e., building layout and combustible contents which provide potential fire sources) and the potential impact of the analysis on the project direction. As a project passes through the steps of feasibility, concept design and schematic design, FPEs are able to refine their initial ideas using more complex tools as appropriate.

Ultimately, many projects which require performance-based analysis involve complex building geometries, which present challenges for the use of algebraic and zone models. As such, given the availability of CFD fire effects tools, and the fact that they can handle more complex geometries, they can appear to be the 'best' candidates for assessing the fire protection design of such projects. However, due to computational constraints (in terms of processors which manage the computational time and in terms of usable memory which sets up the limits of the refined computational grid), it may not be practical or cost-effective to perform one, let alone a series of detailed CFD simulations. In such cases, a decision often needs to be made regarding the trade-off between complexity and time. In the end, it may be that the FPE has to rely on less complex fire effects tools from a time perspective, while demonstrating that the less complex tools are validated for handling the complex geometry (i.e., the FPE needs to demonstrate how the uncertainties related to adapting the complex geometry for less sophisticated tools is not significantly or inappropriately changing the outcome of the engineering solution).

While time constraints may be an issue for practicing engineers, and time and complexity trade-offs may be required, this is not the case in other environments, such as academia, research and high risk or hazard industries. In the academic or research environments, for example, it is not uncommon for multi-year studies to be conducted. Such studies may involve developing new tools, expanding existing tool

capabilities, and assessing better ways to apply existing tools to solve complex engineering problems.

An example of a long-term study dealing with better ways to use tools to solve an engineering problem can be illustrated by Francesco Colella's PhD thesis titled "Multiscale Modeling of Tunnel Ventilation Flow and Fires" (Colella, 2010), conducted at the Politecnico di Torino. His research objective is related to the design of smoke extraction in tunnels of several kilometers in length. In this case, a dichotomy exists between the needed accuracy to simulate the flows around the smoke extractors and the fire, which requires describing the local environment with cells of a few centimeters, and the smoke flow along the whole tunnel, which requires millions of cells and a manageable computational time to perform a series of scenarios to test the smoke control system. In the referenced work, this dichotomy led to the formulation of a method allowing the coupling of a CFD fire effects tool with a 1-D ventilation network tool. The outcome is a hybrid tool where information is transferred between the tools and a formula describing the minimum extent of the CFD computational domain where results are similar to the ones estimated with the full CFD representation of the tunnel.

For an example of a very particular and highly regulated sector which is high-risk / high hazard, one can consider efforts within the nuclear power industry, where multi-year projects involving nuclear power plant operators, researchers, governmental agencies and regulators, have been undertaken (Barrachin *et al.*, 2000; Siu *et al.*, 2008). In this environment, not only have there been sustained research projects aimed at tool development and assessment (e.g., NIST/NRC efforts), but also development of a process for applying different level of complexity tools at different stages in the assessment and design process within a general quantitative (or probabilistic) risk assessment (QRA or PRA) framework. For example, within a QRA process, different types of fire effects tools can be selected as follows:

- In the first instance, simple tools which can be quickly applied are utilized in order to screen out fire scenarios which would have no impact on the QRA. This first level of analysis primarily consists of applying algebraic models that can be edited in a spreadsheet for handling thousand of calculations. Since this application is aimed at the elimination of the fire scenarios which are not relevant for the QRA, it only requires coarse description of the domain and conservative assumptions of the fire development.

- A second more detailed level of analysis can then be conducted by applying more complex fire effects tools to the remaining scenarios. The specific application here is to determine quantities that would actually be input for the QRA related to fire risk. The events to be considered may be framed in time periods of several minutes (e.g., time to the first correcting action) to several hours (in cases where the fire has been spreading and more and more correcting actions have to be taken in order to maintain core safety). Because thousands of simulations may be required to understand the risk, and if the compartments can be characterized with simple geometries (e.g., "shoe box" shaped rooms), application of a zone model appears to be the optimum solution in order to get the corresponding fire QRA input data.
- Once specific areas of concern are identified, CFD tools can then be used to handle specific scenarios involving geometries, such as cable trays supporting the transmission of power or control information regarding core management or safety. In such cases, detailed local information is needed to describe the combustion and flame spread in cables trays, which constitute at the same time extended fire areas and targets important for the core safety in the global QRA.
- material properties not only describing the combustible contents but also the other building elements which "absorb" heat and fire effluents as well as the load-bearing elements,
- initial and boundary conditions, including initial temperature in and outside the built environment and the ventilation conditions (initial conditions including the window and doors status (opened or closed) as well the boundary conditions (how the doors are leaking or how the mechanical ventilation network is set up).

The final attribute which can be used to assess the appropriateness of a tool for a given application is related to the application itself; what is being assessed, and what features of a tool are required to support that assessment. For example, an application could be related to assessing fire propagation inside the room of fire origin with respect to the safety of the occupants in the room. In that case, tools would be needed to assess the fire spread from the 1st burning item to the subsequent ones until the flashover is reached. Fire effects tools including models assessing flame characteristics, ignition by radiation fluxes, etc. would then be considered. Using a tool which is too coarse for the application may not yield the level of information required to make a good assessment. By contrast, the application purpose may be to consider the safety of occupants remote from the compartment of fire origin, without a need to focus on how the fire initially develops. In this case, the application is more concerned with species production and spread outside of the room of origin than with the fire development. In these cases, the same tool may be appropriate to solve different parts of each problem, but in different ways and at different levels of complexity. In the first instance, a CFD model may be needed to obtain the degree of analysis needed in the room of origin, and a zone-model may not yield sufficient detail. In the second case, however, a zone model may be appropriate for simulating initial conditions in the room of origin, with a CFD model need to assess smoke and hot gas spread outside the room of origin.

Data availability and fire phenomena

Two additional critical criteria in the selection of a candidate tool for a given application are the availability of the input data required to effectively apply the tool, and the making sure that the fire phenomena that the tool simulates matches the assessment needs.

Assuming for this discussion that the three types of fire effect tools are available and have been validated to correctly represent the physics for a given application, the next criterion regarding appropriateness of a tool for an application could then be determined by the amount and goodness of information that can be collected for the data input needed by the different tools. The recently published *SFPE Guidelines for Substantiating a Fire Model for a Given Application* (SFPE, 2011) provides a good starting point, noting for example the need to identify:

- details of the spatial domain representing the built environment,
- fire design scenario timeframes (from several minutes for a single room flashover application to several hours for assessing the collapse of a structure due to a generalized fire),

EXAMPLES OF STUDIES TO BE CONDUCTED RELATED TO THE USE OF FIRE EFFECTS TOOLS FOR GIVEN APPLICATIONS

It is suggested that the above issues form the basis for development of 'best practice' guidelines for selecting fire effects tools based on their appropriateness to the application at hand. These guidelines would be used in collaboration with related guidance, such as the *SFPE Guidelines for*

*Substantiating a Fire Model for a Given Application*¹ and *SFPE Guide to Predicting Room of Origin Fire Hazards* (SFPE, 2007a) and other such guidance, and would support a wide range of industry stakeholders, including:

- FPEs, to select the appropriate tool to solve their engineering problems,
- researchers to develop more tool functionalities and to increase tool validation, and
- the regulators and authorities to have more confidence in the engineering solutions when these tools are used.

However, in order to ultimately produce comprehensive ‘best practice’ guidelines to assess the appropriateness of a fire effects tool for a given application, it is suggested that a series of both generic and specific studies need to be conducted. The intent of these studies is to utilize multiple participants to develop data and case history to illustrate a wide range of issues, such as level of detail needed in building configurations for different types of problems or occupancies (e.g., life safety in hospitals versus apartments), or detail required in characterizing ‘fuel packages’ for use in models to meet assessment objectives. Below is the outline of the selection process and examples of generic studies that can be conducted for supporting the tool selection process. As described in the previous section, these studies ultimately have to be based on cases representing a given application, as results of such studies are highly dependent of the given application definition and context.

Process outline and generic ‘test bed’ environment for guiding selection of the right tool for a given application

In this effort we aim to demonstrate that by applying a specific process for a set of ‘test bed’ building configurations of a particular use (categorized by building occupancy groups), for a particular range of configurations (determined by design fires scenarios) targeting a particular outcome (safety objectives including life safety, property protection, business continuity, etc.), the results of each ‘test bed’ study, defined in that context, will yield data which will lead to a guideline of the selection of appropriate tools for that type of situation.

¹ The difference between the existing SFPE Guide and the proposed approach is that the existing guide helps to justify use of a tool, once selected, and the proposed approach helps guide selection of an appropriate tool.

The reason for collecting ranges of buildings by building occupancy groups is to obtain an extensive database of information related to layouts of representative buildings, rather than individual building layouts, which can then serve as the basis of guidelines that are occupancy group based (e.g., guide to application of fire effects tools in healthcare occupancies). Also, in a broader context, determining the building occupancy group is the first step in assessing its fire protection requirements whether one follows prescriptive building regulations or the performance-based design process (a first step being to define the scope of the project, notably by identifying the intended use and occupancy of the building (SFPE, 2007b)).

The process that is envisaged to conduct a ‘test bed’ study case is composed of the following steps:

1. Identify occupancy group for study focus
2. Collect building configurations for study
3. Identify study parameters (e.g., selection of tool for assessing safety objectives)
4. Set up building layouts for fire effects (zone models, CFD models) and their evacuation counterpart
5. Identify objectives and criteria (life safety, property protection, mission continuity)
6. Select fire scenarios for study (additional guidance in other work)
7. Perform the fire (and evacuation) simulations with the different sets of tools (and for different mitigation strategies, as appropriate)
8. Analyze the results in terms of the safety objectives
9. Assess ability of tool to address defined performance issue
10. Conclude by establishing guidelines related to the tool comparison process and its outcome.

With respect to the ‘test bed’ studies, it is important to note that each individual case does not need to be validated; that is, the objective of performing the case studies using different tools is not to increase the validation domain of the tools, but to obtain information about the application of the different tools for attaining different objectives. Likewise, the case studies themselves do not result in *de facto* design fire scenarios for the considered building occupancy group. These two objectives (increasing the validation domain of tools, selecting fire design scenarios for performance-based applications), while important to the overall process, are out of the scope of the studies presented in this paper. Cf. (Alvarez and Meacham, 2011) for more information.

Also, it is important to have participants undertaking the case studies from across the whole spectrum of the fire engineering community – from consulting engineers to regulators, and by engineers and regulators from around the world. Such diversity and breadth of participation would provide the potential to add more tools, more fire scenarios, and more variants in the building configurations, and the resulting ‘test bed’ study guidelines would be more directly included in the larger performance-based fire protection design framework. (Having 20 engineers from 10 countries apply tools and fire scenarios that they select for a common set of objectives for a set of 5 healthcare configurations would yield much more robust data than 2-3 engineers applying the same tool to a single building configuration.)

While processes similar to the above exist at a generic level (e.g., *SFPE Guide to Performance-Based Fire Protection*) they lack the detail and the data to help users make informed judgments. This approach aims to both provide added detail to the process and data to support the justification of the tool selection.

Specific case studies: issues related to the use of CFD fire effects tools

The use of CFD fire effects tools is quite complex and necessitates that the user also deals with uncertainties related to the use of these tools. Here are some examples of issues related to the “user effects” related to CFD fire effects tools – issues that would have to be addressed when using this kind of tools in Step 7 of the ‘test bed’ study process.

Grid selection for a better optimization of computational meshes of a CFD fire effects tool

Spatial domain can be categorized as one source of "user effects" uncertainty (SFPE, 2011). For a CFD fire effects tools, grid sensitivity should be performed in order to determine at what grid refinement the desired outcomes become grid independent. However, care should be taken to assure other design objectives are met as well.

For example, Sztarbala (2011) indicates that "when LES model is used, the number of grid elements must be increased. A maximum edge length of 0.15 m is recommended for grid elements in flow-relevant areas. For other areas the maximum edge length should not exceed 0.50m". However, these grid cell sizes may not be compatible with the time and computing resources of FPEs in the consulting environment, as they would require extensive parallel processing power and memory. In addition, these grid sizes may not be needed for the resolution of analysis required. In addition, some CFD tools allow the

definition of multiple meshes with different grids, which allows some flexibility. However, communication between the different grids may affect the results. Looking at this issue in a more comprehensive manner can lead to developing user guidance when designing for all computational grids.

Influence of detailed geometry on the results of the simulations

It is known that the computational mesh, which simulates the spatial domain of the project of interest, has an influence on the results provided by CFD fire effects tools. However, there is no real guidance on how to deal with this issue. For specific outcomes of fire scenarios, it may be necessary to perform a simulation with a high level of details. Because of calculation time it would require, such simulations which include details of building contents and structural elements are rarely performed in practice because they are not compatible with the time constraints of engineering studies. To address this issue, it would be beneficial to establish guidance on the degree of detail needed for particular design aspects (e.g., contents, structural features) that are "just" needed with respect to the degree of details required in the description of the building geometry.

Looking at this issue would help to:

- indicate whether the simulation of all a building in 3-D is necessary,
- determine the minimum degree of details needed to get access to the information, describing temperature profiles, smoke and toxic fire effluent propagation required to perform an analysis of the evacuation of building occupants.

In addition, by looking at different safety objectives for the same building configuration, one could verify if the building description established for an occupant evacuation could be used for design fire scenarios related to property protection or business interruption.

Detailed geometry description v. computational time and result accuracy

CFD fire effects tools allow a refined description of the building structural elements and contents, which represent heat sinks and obstacles that can modify the buoyant smoke and hot gases trajectory. Whereas these structural elements and contents can be described in detail in 3-D simulations, and these details may influence the results of the simulations, but at a cost of an increased computational time, a series of simulations should be performed in order to estimate how the detailed geometry description affect the result accuracy to the detriment of computational time.

Verification of the consistency of results

As indicated in Chapter 5 of the *SFPE Guidelines for Substantiating a Fire Model for a Given Application* (verification and validation), using multiple tools for the same configuration may demonstrate that the "results make sense. Especially for more complex models, performing an analysis with another tool could result on a non-sensical result" (SFPE, 2011). While this kind of analysis is not a primary objective of the ‘test bed’ studies presented in this paper, results from the ‘test bed’ studies of fire effects tools for a given application can serve as a basis for a verification of the consistency of results between different types of tools.

Inclusion of Hybrid modeling in the ‘test bed’ studies

As presented previously, attempts have been made to create hybrid tools which can combine the accuracy of the CFD model with the computational speed of zone models. Other recent examples of such hybrid tools for estimating fire effects concern:

- the simulation of large geometries such as large buildings or large passenger ships, with a CFD model / zone model hybrid developed by the University of Edinburgh (Burton *et al*, 2011),
- the estimation of HVAC flows in case of fire in a building based on a coupling of a HVAC network model with the Fire Dynamics Simulator (FDS) developed by Floyd (2011).

Hybrid tools appear to be promising new tools, which can also be included in the ‘test bed’ studies presented above. It will also be important to analyze the process the hybrid models underwent so to collect information not only about the computational time gain with minimum accuracy loss, but also the assumptions related to the fabrication of the hybrid tools as these assumptions may be highly dependent on the applications of the tools, that is to say the set of configurations the tools were designed for.

ORGANIZATION OF THE ‘TEST BED’ STUDIES

As presented above, the first steps in the process are obtaining layouts for occupancy groups and defining analysis objectives. Once this has been done, the analysis starts with setting up the building layouts.

Setting up building layout (Step 4)

The following process for generating building layouts for FDS from different building configuration sources has already been established and is presented below.

Process to generate “ready-to-use” building layouts for Fire Protection design purposes

Architects design the overall building layout using 3-D software that is able to render the geometry of the rooms, spaces and exit pathways. Furniture and building contents, as well as nature of the structural elements would be described in this software files. Architect engineers dealing with the description of the building systems, such as the HVAC system, also describe their data using 3-D software. To facilitate the ‘test bed’ studies of real building geometries for a range of occupancy groups, it would be helpful to have a set of ‘ready-to-use’ building layouts. The process in order to get these layouts for FDS simulations, from architect design files, is described in Figure 2 below.

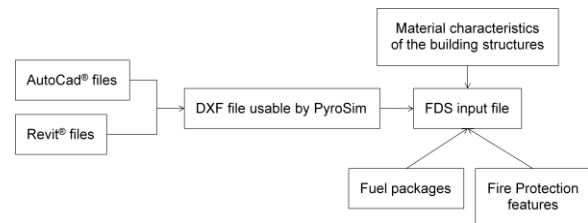


Figure 2: Process currently followed to create FDS building layouts.

In the 8th *International Conference on Performance-based Codes and Safety Design Methods* (SFPE, 2010) the case study was related to a 6 story office building where 4 stories had to be converted into a night club. Table 1 presents the different fire effects and evacuation tools used by the participating countries. Compiling the building layouts presented in Table 1, as well as the fire scenarios selected by the different countries would constitute a fast way to carry the 1st tasks of a ‘test bed’ study case related to that configuration.

Table 1: Fire effects tools and evacuation tools used by different countries (SFPE, 2010)

| Country | Fire effects | Evacuation |
|-------------|---|------------------|
| New Zealand | Zone model (BRANZFIRE) | Algebraic models |
| USA | CFD model (FDS) | Algebraic models |
| Australia | Zone model (CFAST) | PATHFINDER |
| France | Zone model (CIFI2009) and CFD model (FDS) | Algebraic models |
| Hong Kong | CFD model (FDS) | MODELMAKER |
| Japan | Algebraic models and zone model (BRI2002) | SimTread |
| Sweden | CFD model (FDS) | STEPS |

In addition, other potential sources of building layouts are NIST investigation reports (Station nightclub, office building of the Cook County hospital or part of the World Trade Center) or published articles including building layouts for estimating fire consequences or even crowd evacuation.

Going forward, however, it would be helpful to obtain building layouts, from architects, which represent a wide range of building configurations over a spectrum of building occupancy groups. Table 2 presents a list of building configuration layouts to be implemented in the near future, with a focus on getting the description of the spatial domain in FDS.

Table 2: List of building configuration layouts to be implemented in the near future

| Building occupancy type | Example |
|-------------------------|-------------|
| Assembly | Library |
| Health care | Hospital |
| Educational | High school |
| Residential | Dormitory |

Examples of building layouts are included in the conference presentation slides.

To facilitate use by a broad range of stakeholders, the building layouts will ultimately be distributed to a Google user group to be tested across the world (as materials and fire protection features vary with countries) and versions of these layouts usable for other fire effects tools as well as for evacuation modeling will also be developed. Before the end of the year, the layouts will be distributed to a small group of fire protection engineers across the world for some feedback. It should be noted that these configurations will not include any fire components or fire protection features. The information gathered in the Google user group on the building configurations is aimed to be as exhaustive as possible in describing the building contents and occupants so to remain accessible and usable even for upgraded versions of the current tools or future tools.

Selecting fire scenarios (Step 6)

Whatever the fire effects tool, be it based on algebraic models, zone models or CFD models (when not using a pyrolysis model), the description of the fire remains a user input data of crucial importance. A primary component of the fire design scenario is the fire design curve which represents the evolution with time of the heat release rate (HRR) of the corresponding fire. This “HRR curve” will allow the calculation of the heat hazard component of the fire.

In parallel to the evolution with time of the HRR, the evolution of the fire effluents (smoke, toxic and irritant products) is also essential to estimate the toxic hazard component of the fire.

When using fire effects tools, two options for establishing the HRR curve are possible:

- the HRR curve can be predefined, from ignition to extinguishment, and used as an input for all the different types of fire effects tools, or;
- the HRR curve can be left to the different fire effects tools estimate as follows: the location and nature of the 1st burning item are given and the tool has to assess fire propagation to the other fuel items which nature and position are known.

Whatever option is selected, and because no pyrolysis model is intended to be used in the present scope of the ‘test bed’ studies, the user has to provide HRR curves for single fuel packages, describing the evolution of the HRR they can individually produce once ignited.

HRR curve database

When looking for heat release rates for building contents, from furniture to curtains, from appliances to even cars, a primary source of information is the SFPE Handbook chapter dedicated to heat release rates, written by Babrauskas (2008). This chapter contains numerous references that can lead to a significant amount of data from furniture calorimeters, including heat release rates evolution with time, soot and toxic component yields. In addition, by reviewing NIST publications alone, some fifty different experiments have already been included in a database, along with the available snapshots and videos. This number will be expanded by looking at more NIST studies, as well as tapping into test data from around the world. Before the end of the year, it is planned to distribute the database to a small group of fire protection engineers across the world for feedback and contribution to the database.

Smoke and fire effluents

Smoke and fire effluent production and movement quantification are an important part of the engineering problem, related not only to life safety objectives, but also to property damage, and environment protection. Products of combustion can have an impact on people safe evacuation (affecting their safe escape), on building contents (damaging costly pieces of equipment or historical artifacts), on business continuity (causing the malfunction or the destruction of manufacturing goods, processing chains, or equipment assuring the safety of the process), or on the environment (when toxic or hazardous materials are released in quantities that can impact the environment). Thus, it is essential to

estimate the nature and the kinetics of the fire effluents.

In solving engineering problems related to fire effluent impact on building occupants and contents, it is necessary to assess the production, transport and deposition/absorption of these effluents inside the building and also outside for environmental safety objective. Transport and deposition of airborne particles constitute very complex subjects by themselves and these phenomena are greatly influenced by the building layout, which adds another study to the ones already presented in the previous sections dedicated to the building layouts. Production of fire effluents are related to the fire spread on the burning combustibles, which include the also complex pyrolysis processes of usually heterogeneous materials, as well as the ventilation conditions around the fire scene (i.e. the fire is under-ventilated or not).

When reviewing NIST furniture calorimeter tests, it was noted that the information related to the production of fire effluents was rarely provided. Additional information may be collected when material properties are collected, i.e. at laboratory scale, such as soot yields, CO yields, CO/CO₂ ratios, etc., if possible for pre-flashover and post-flashover conditions, as these values are dependent of the ventilation conditions around the burning fuel item.

'Combustible packages' for 3-D simulations

The objective of providing 'combustible packages' ready for 3-D simulations came from the FDS user point of view and the availability of third party software developed in order to facilitate the creation of FDS input data files. Indeed, if such software is able to create and duplicate building elements as presented in the previous section, why not trying to do the same for combustible elements.

For FDS, the heat release rate is defined by a surface area, that is to say, that the specification of the burning areas is required. Because of this requirement, the evolution with time of the burning areas has to be included as an input data. In some cases, the burning area is set up as a constant and at the maximum of the combustible object area(s). Nevertheless, for complex setups of combustible building contents, which have been burnt in furniture calorimeter, videos clearly show the flame propagation from the ignition localized point to the complete flame engulfment of the set up, which can occur several minutes later as a peak of HRR.

The description of the flame spread over the combustible building content is necessary when

assessing the fire spread inside the compartment or space where the content is located, as the estimation of the ignition of the second burning item is dependent on the radiation received by this target from the 1st burning building content. This heat transfer mechanism can be estimated using a CFD fire effects tool so it requires the flame characteristics which are dependent on the evolution with time of the HRR and of the burning areas. It should be noted that such a detailed characterization is not required in the far field, that is to say when the given application is related to the phenomena that occur outside the room of fire origin, i.e. for example when assessing the smoke spread in exit pathways outside the room of fire origin. The degree of details for the 'combustible packages' is also dependent of the given application, as well as the other input parameters presented in the previous sections.

Even for relatively simple building content geometry, such as a wood dresser, the question of the burning areas remains: if all the HRR is distributed at the top area of the wood dresser, activation of a heat detector would be quicker than if the HRR is distributed on the lateral areas of the wood dresser. In the latter distribution, ignition of a second burning item located in front of the wood dresser would be quicker.

Since some snapshots and videos are available from the NIST for different building contents including a wood dresser, it was then decided to study the influence of the burning areas evolution with time on the ignition of a second burning item and on heat detection at the ceiling level.

NIST/BFRL experiments related to the combustion of a loveseat, a mattress (with center ignition and corner ignition) and a wood dresser were selected. Burning areas were defined according to the flame spread pattern on the burning item. Fractions of the HRR were then distributed among the defined areas so the resulting modeled flames would have the same length as the ones in the snapshots or video. In the corresponding FDS simulations, devices were located in front and at the periphery of the burning item and temperatures were recorded under the ceiling to estimate the activation time of thermal elements located there.

Detailed analysis of the results will be available in the near future. Even so, thus far the particular study shows the feasibility of such a detailed description of combustible burning items. By the end of the year, a primary series of 'combustible packages' will be set up and distributed to a small group of fire protection engineers across the world for some feedback.

Examples of 'combustible packages' for FDS are given in the conference presentation slides.

Creation of a fire protection engineering 'test bed' study pool (Step 7 to Step 10)

Performing Step 7 and Step 8 of the 'test bed' study process requires significant time and resources to collect the targeted data. It is not feasible for a single entity from within the fire protection engineering community to conduct all the needed studies – not only from a resource perspective, but because each sector within the FPE community has its own goals and objectives, prerogatives and time and resources constraints. In addition, Steps 5-10 require participation of people from all sectors in any case.

Conducting such studies with all these different people would benefit all of them in different manners:

- The consulting companies would acquire better understanding of the use of tools for a given engineering application, optimizing their resources and time;
- The students and professors in Academia could use the case studies as practical examples of engineering problems;
- The governmental agencies could set up research programs focusing on the problems and needs of the engineering community;
- Engineering societies could elaborate guides and guidelines improving the use of engineering tools for given applications, where appendices would be added with the results of specific cases;
- Regulators and Authorities having jurisdictions would consider the improvements in the use of tools in projects based on performance based design fire protection options.

The aim, then, is to encourage the establishment of a sector-wide and world-wide group of users to participate in the 'test bed' studies outlined above, with the objective of developing data which will lead to a guideline for the selection of appropriate tools for specific building occupancy types and configurations.

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INFORMATION

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