A methodology to create a design fire, NIST workshop Gaithersburg 2002-03-04--2002-03-06

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The present way of creating a design fire

Performance-based fire safety engineering (FSE) is an important tool for constructing fire safe environments. The efficiency of such a tool is dependent on several areas of knowledge, such as the behaviour of humans in relation to fires and of course the nature of the fire itself. However, much of the necessary information for using the FSE tool efficiently is today either lacking or poorly understood [1].

A fire hazard analysis is of course relying on the assumptions of fire growth that is done by the engineer. The time scale for the fire is depending on the selection of the design fire and this time scale will in most cases determine the time for further fire spread, the probabilities for casualties, the time available for escape and so on. Therefore, the method to arrive at a plausible design fire has been the objective for much research work over the years. However, methods that are envisaged internationally are still simple and rather crude and needs to be further improved to be more versatile.

ISO/ TC 92 Fire Safety, SC 4 Fire Safety Engineering, is working on a series of documents covering the topic of fire hazard (ISO/CD 13387-13394) [2,3,4,5,6,7,8,9]. These documents are written in very general terms leaving to the consultants to interpret the documents. In the document ISO/ CD 13388 Fire Safety Engineering- Design Fire Scenarios and Design Fires, it is more the philosophy of creating a design fire that is emphasized than giving actual examples of how to do it.

The most frequently suggested design fire is the t^2- fire where the heat release rate is described by $\dot{Q} = \dot{Q}_0 \left(\frac{t}{t_g}\right)^2$, $\dot{Q}_0$ is normally chosen to 1 MW. The recommendations of t_{ref} are 600, 300, 150 and 75 seconds for *slow*, *medium*, *fast* and *ultra fast* fires respectively.

In Annex A in ref. 3 proposals for t^2- fires are given for various design fire scenarios, see Table 1.

Table 1. Design fires as given in ISO/CD 13388

Design fire scenario	**Category**
Upholstered furniture and stacked furniture near combustible linings	*Ultra fast*
Light- weight furnishings	*Ultra fast*
Packing material in rubbish pile	*Ultra fast*
Non- fire retarded plastic foam storage	*Ultra fast*
Cardboard or plastic boxes in vertical storage arrangement	*Ultra fast*
Office furniture- horizontally distributed	*Medium*
Displays and padded work- station partitioning	*Fast*
Bedding	*Fast*
Floor coverings	*Slow*
Shop counters	*Medium*

Nordic regulators have published a document that assigns a design fire as a function of type of occupancy. This was inside a committee called NKB, "Nordic committee on building regulations". NKB [10] gives a selection of design fires depending on the type of building, see Table 2.

Table 2. The NKB design fires.

Category of use	α (W/s^2)
A (dwellings)	12
B (hotel)	50
C (shops, public spaces)	190
D (schools, offices)	50
E (industry of large fire hazard)	Not applicable

The design fire is expressed as $\dot{Q} = \gamma_q \alpha t^2$ where $\dot{Q}$ is the HRR, α is given above, t is time and γ_q is a partial coefficient. There are no recommendations on how to use the partial coefficient. This expression gives the same result as the earlier mentioned formula $\dot{Q} = \dot{Q}_0 (t/t_g)^2$.

The discussed methodology to create the design fire and criteria for selection of input data is at best based on generalisation of fire behaviour data and fire statistics. At worst it is just a pure guess. The principle of the process is shown in figure 1.

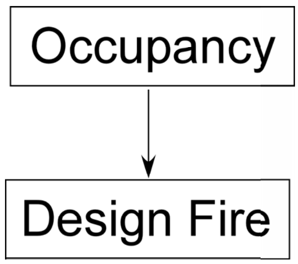

Figure 1. ***The present way of creating the design fire***

It is seen from the figure that the resulting design fire is arrived at directly as a result of selecting the occupancy. There are of course cases when some calculations take place, but the procedure does not require that, as the fire growth rate is already given by the default curves. The maximum HRR of the design fire must of course be defined, as it cannot grow indefinitely. This is often done by calculating the limit for ventilation control, sprinkler action etc. However, adding information of the characteristic fire properties of the products involved in fire would add considerably to the accuracy of the resulting design fire assumption, especially for the early stages of the fire. To do that we need product specific data that are representative of groups of products. The building products as well as the building contents needs to be considered in that respect.

The characteristic fire growth

Using the characteristic fire growth from a product as additional input when creating a design fire implies that the process shown in Figure 1 is modified as shown in Figure 2.

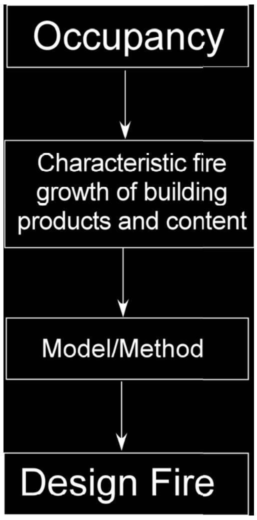

Figure 2. ***The methodology to create a design fire by using characteristic fire growth of products***

The occupancy is defined in the same way as for the default method, Figure 1.

The characteristic fire growth of the building products and building contents can be found using different approaches. This could be the actual HRR history of the product, the exact approach, or it could be a generalised HRR history of a product category. Apart from being representative of the burning behaviour of the product in question the characteristic fire growth must be in a format that is useful for modelling. At SP we have used data from the Cone Calorimeter in describing linings and from the Furniture Calorimeter in describing upholstered furniture

The model or the method used to create the design fire can be very simple. However, it requires that the influence of the room/space where the fire takes place is considered. This is especially true for the linings. It also requires that the interaction between the building content, furniture etc, is accounted for. This can be done by simple methods using model room sizes and simply adding the effect from the furniture, see [[11]].

Another alternative is to use a computer fire model. Some zone models can accept data from the Cone Calorimeter on linings as well as furniture HRR, e.g. Branzfire and Cone Tools. Thus the room scenario in question is input as well as the relevant HRR curves. This also becomes a simple and quick procedure that can be done on any laptop.

For very complicated spaces the zone model becomes uncertain. This case can be handled by using a CFD model. CFD is complicated, requires powerful computers, time and qualified staff. Therefore this case may be useful only for large projects.

In the power point presentation of the NIST workshop an example is given on how to create a design fire based on the characteristic fire growth of linings, data from the Cone Calorimeter, combined with characteristic data on upholstered furniture from the Furniture Calorimeter.

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[1] Babrauskas V., *Performance-Based Fire Safety Engineering Design: The role of fire models and fire tests*, Interflam Conference, Edinburgh, Vol. 2, pp 799-808, 1999

[2] ISO/ CD 13387 Fire Safety Engineering- The Application of Fire Performance Concepts to Design Objectives.

[3] ISO/ CD 13388 Fire Safety Engineering- Design Fire Scenarios and Design Fires

[4] ISO/ CD 13389 Fire Safety Engineering- Assessment and Verification of Mathematical Fire Models

[5] ISO/ CD 13390 Fire Safety Engineering- Subsystem 1: Initiation and Development of Fire and Fire Effluents

[6] ISO/ CD 13391 Fire Safety Engineering- Subsystem 2: Movement of Fire Effluents

[7] ISO/ CD 13392 Fire Safety Engineering- Subsystem 3: Fire Spread Beyond the Enclosure of Origin

[8] ISO/ CD 13393 Fire Safety Engineering- Subsystem 4: Detection, Activation and Suppression

[9] ISO/ CD 13394 Fire Safety Engineering- Subsystem 5: Life Safety

[10] *Funktionsbestemte brandkrav og teknisk vejledning for beregningsmaessig eftervisning*, NKB Utskotts- och arbetsrapporter 1994:07, ISBN 951-53-0024-X.

[11] Höglander K. and Sundström B., Design Fires for Preflashover Fires, SP Swedish National Testing and Research Institute, Fire Technology, SP Report 1997:36