Objectives and Pitfalls in the Simulation of Building Fires with a Computer

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The complex interactions between a building and a fire are being studied using the National Bureau of Standards computer facility. By highlighting the information needs for a successful calculation, the fire simulation study provides a guide to future research.

An important part of fire protection engineering is predicting the probable course of a building fire from ignition to extinguishment. The author has tried to carry out a detailed predictive fire history calculation that treats the whole building fire system, as distinct from calculations about technically isolated areas. Detailed treatments of some parts of a fire development can be found in the literature, but due to their length, it has not yet been practical to incorporate them into a scheme for the whole building fire system. This paper deals with a synthesis of the information on fire development into a calculation of the whole fire history. It emphasizes the problems associated with such a synthesis and their solution. Insofar as the study is able to represent correctly actual building fires, it provides a useful tool to the fire protection engineer.

Four elements must be brought together if this analysis is to succeed. First, data about the building must be assembled. Needed data are often not available, and the available data are not always useful. Second, the data must be arranged and stored. The magnitude of this task requires automation of the arranging and storing process. Third, the fire must be described. This involves developing a clear concise notation for recording the state of the fire at any point and time, and developing a

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clear, usable understanding of the physics of the fire. Finally, and most important, the interaction between the fire and the building must be analyzed.

DESCRIBING THE BUILDING

A data file on those features of the building pertinent to the fire must be obtained and stored where it can be searched as needed. This data file will have two general characteristics independent of its detailed form; it will reflect the amount and type of combustible to be found at a particular location and the effect of a fire at one location on all other locations accessible to it. In the terminology of the structural engineer, each location has an associated "loading" and an "influence coefficient."

For a simple case, the building may be described by identifying each room by number, listing its contents (the loading), and stating the conformation of the walls, floor, and ceiling (the influence coefficients). More generally, the building may be subdivided into a number of rectangular blocks, or cubicles. An address, which is the equivalent of the room number, is assigned to each cubicle. Under the address a suitable occupancy description, the loading, and the influence coefficients are recorded.

With this scheme, the ability of the calculation to locate a given event is limited by the size of the cubicles. Smaller cubicles give better spatial resolution, but require more cubicles to describe a building of the same size. The number of cubicles needed may be quite large. For example, to describe a particular 100,000 ft² unsubdivided warehouse with a minimal recognition of its actual contents required almost 5,000 cubicles. For comparison, a good size single family house described to the same level of resolution would require about 44 cubicles. These numbers have importance when we consider storing the influence coefficients. Ideally, each cubicle should be allowed to interact with every other. But this means that a description containing N cubicles will include \(N(N-1)/2\) influence coefficients. Although it is practical with a 44-cubicle description to store 946 influence coefficients, the 12 ½ million associated with a 5,000-cubicle description are just too many.

A compromise must be made to reduce the number of influence coefficients. The one chosen limits the influence of each cubicle to its six nearest neighbors. This brings the storage problem back into reasonable bounds, but puts a constraint on the fire description, since allowable interactions are limited to a succession of short range effects. Most processes of heat and mass transfer do act step by step through contiguous cubicles. However, radiation is one process that clearly can act at a distance. At a slight cost in program complexity, radiation can be accommodated within the nearest neighbor interaction scheme. Thus, a stack of rectangular blocks, each described by its contents and its interaction with the six adjacent neighbors, seems to form a suitable and manageable basic building description.