THE INTEGRATION OF COMPONENTS OF FIRE TECHNOLOGY

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ABSTRACT

Fire safety systems in large buildings are likely to be complex and may be designed independently of other systems. This means that the interactions and interfaces between the fire safety systems and between the environmental control systems and the fire safety systems may not be carried out properly. Many large, recent buildings have many technological component systems that are used for the control of the environment within the building. Because of the "special" nature of the fire safety systems there is little consideration is given to the possibility systems with a dual function. However, many of the functions of fire safety systems are extensions of systems that provide the day to day control over the internal environment. The present world-wide trend towards the establishment of performance codes, and regulations, will enable the functional design of all systems and thereby allow closer integration of the "ordinary" and "special" systems. Some aspects of the functional and performance characteristics of systems in buildings are introduced and discussed. Special reference is made to the contributions of the systems to the minimisation of fire damage.

ESSENTIAL SYSTEMS

Six essential requirements for buildings have been defined [1] and each should be fulfilled in both new and existing buildings. The requirements are: 1 Mechanical resistance and stability; 2 Safety in case of fire; 3 Hygiene, health and environment; 4 Safety in use; 5 Protection against noise; and 6 Energy economy and heat retention. Each of these requirements interacts with all of the other requirements at several levels of consideration. These include the conceptual, the functional and the system hardware levels. For example, the elevated temperatures of a fire environment are an addition to the loads that structural components need to withstand noting the reduction in stress resistance with increase in temperature. Fire is then a strong conceptual aspect of structural design. Hygiene includes the cleaning performance of surfaces and the quality of the air in the spaces within the building. The coefficient of friction of the floor and the tactile design of the surfaces impact on the "ease of escape" of the occupants by influencing the slipperiness of the floor – a functional consideration. The properties of cleaning materials could alter the "surface spread of flame" characteristics of the surfaces especially those combustible materials that influence the probable rate of fire growth on the surfaces. The "safety in use" requirement requires a detailed consideration of the presence of sharp edges, points, obstructions in and around the building and the design of components such as staircases and the definition of escape routes. The protection of the occupant against noise, either inside or outside the building, is an acoustic design problem that has a clear interaction with the loudness and the intelligibility of any acoustic signal from alarm systems. Energy economy suggests high levels on thermal insulation and low levels of air infiltration and exfiltration. The principal influences on the fire safety in the building will be the minimisation of inter space smoke travel because of the low air leakage design of the external fabric and a decrease in the time between ignition and flashover. The leakage characteristic of constructional membranes within the building is dictated by the selection of the actual components of the membranes.

FIRE SAFETY SYSTEMS

Considering the fire safety systems alone they have a particular set of objectives to achieve. These have been listed by Bukowski [2] as:

Prevent the fire or retard its growth and spread;
Protect the building occupants from the effects of the fire;
Minimise the impact of the fire; and
Support fire service operations.

The systems that are needed to fulfil such a list may be management systems as much as physical components, such as fire extinguishers, that are purchased and installed as a contribution to the minimisation of the damage caused by a fire.

The normally discrete fire safety systems are regarded as different to the other systems that operate continually in the building as they are only called upon to operate when a fire emergency is manifest. Because of the infrequent use of the fire safety systems regular maintenance and testing become very important to maintain the initial confidence in the potential performance of the systems that will contribute to the minimisation of the damage potential of a fire. This situation leads to the concept of using the day to day systems as emergency systems. This concept is likely to be acceptable for those systems that are intended to fulfil the functional requirements that are within the scope of fire safety design. For example, illumination and air handling systems.

The need for light, natural or artificial, in a working building is essential. If the supply of light is removed then emergency lighting is needed to maintain visibility and the proper sense of location within the building. If the supply of light is maintained then the process of escape from the building will be made less difficult than when without light. However, the provision of emergency lighting need not be by a totally special fire safety system as the lamps and luminaires can be integrated with the lighting systems for day to day use in the building. This is possible only if the electrical supply to the fittings is carried in cables that are protected from fire. This type of integration can be beneficial aesthetically and economically.

Air handling systems are needed in many large buildings as part of the environmental control, comfort, systems. One of the principal products of combustion, smoke, flows on the air streams generated by the air handling systems until the heat released by the fire generates enough buoyancy force in the smoke for it to flow as dictated by the available heat. It is practicable to use the day to day air moving systems to assist in the control of smoke flow. This can be achieved by increasing the pressure difference across predetermined physical barriers, by making a contribution to the provision of replacement air for smoke extract systems and by acting as smoke removal systems for cool and cold smoke. Such uses have been made possible by the developments in the control systems for services in buildings generally. Dedicated high temperature smoke extract systems are needed for those smoke control designs where very hot smoke is to be extracted from the volume of the building that contains a non-sprinklered fire.

Lighting and air handling systems are somewhat uni-functional but the constructional systems of buildings are usually multi-functional. For example, a wall that is a separating wall – a wall that is designed to control the worst possible fire on one side so that the "cool" side of the wall, in another ownership - suffers no damage. In addition to providing fire resistance through the thickness of the wall it needs to provide security, thermal insulation, structural stability in ambient and in fire conditions and have a surface finish that is appropriate to the function of the adjacent space. This multi-functional aspect of the wall presents the building economist with a problem of the division of the cost of a wall between the several performance characteristics.

PERFORMANCE OF SYSTEMS

The design of fire safety systems has to be carried out at several levels in the development of the design of a building [3]. The first level has been termed the "qualitative design review". This is the stage at which the architectural design is reviewed, the fire hazards identified and then the fire safety problem can be defined in qualitative terms. Then a detailed analysis can be carried out and the quantitative target set for the definition and quantitative design of the discrete fire safety systems. In addition "trial designs" for the fire safety systems may be developed that are considered likely to satisfy the fire safety criteria that have been established. To enable the quantitative design of the systems to proceed a number (6) of sub-systems have been defined [3]. These are:

1 initiation and development of the fire in the enclosure of fire origin
2 spread of smoke and toxic gases within and beyond the enclosure of fire origin
3 fire spread beyond the enclosure of fire origin
4 detection and activation of the fire protection process
5 fire service intervention
6 evacuation procedure.

Each of the subsystems has a number of connections to two or more of the twenty-four characteristic components of fire safety. These include characteristics such as: velocity of smoke and hot gases; rate of heat release; evacuation strategy; and the selection of the design fire. Quantitative design decisions about the properties of the component systems lead to the assessment phase of the process of fire engineering. That the comparison of the outcomes of the quantitative engineering analysis to the acceptance criteria that would be set out in the first stage qualitative review. The approach to these comparisons may be: deterministic; probabilistic; or comparative. The first and third approaches are the most common at this time due to a lack of reliable data on the failure or success statistics for all fire safety systems. The fire engineering approach can be summarised as follows:

ANALYSIS of the fire safety problems and the setting of qualitative and quantitative design targets for all systems;
DESIGN of each system through selection or analytical design for the desired performance;

CONSTRUCTION of each system in the building;
EVALUATION through commissioning of the discrete systems and the total set of systems including the ambient systems that contribute to the total set of systems; and
FEEDBACK of information about the performance of the total- and part- systems and the judgement of deficiency compared with the design targets.

The processes of evaluation and feedback are extremely important to the fire safety engineer as these processes give a measure of the success of the design. In the evaluation phase the interactions between the systems are tested as well as the commissioning engineer making assessments of the compliance of the systems with the appropriate standard.

Overall, the approach to fire engineering outlined [4] above can be termed the performance approach to the achievement of adequate standards of fire safety. The application of performance concepts within fire safety design is gaining wide acceptance in the national and international building industry. In parallel there is a degree of scepticism for this approach by officers of local government - the fire safety officer and the building control officer. This scepticism may be generated by a lack of knowledge in the local authority or such a lack in the developer and/or his design team. Several articles appeared in the July 1996 issue of the "Fire Engineers Journal" give a good summary of different approaches to the execution and the testing of the outcomes of the performance based approach. A recent text [5] sponsored by the UK Department of the Environment may help to give the building design team a better basic understanding of fire and buildings in the present day context. One important deficiency is the lack of guidance for the approach to the selection of the appropriate choice of a strategy for fire safety design and the setting of basic parameters such as the type of fire to be used in the fire safety design. As noted above these are essential parameters to enable fire engineering to be applied.

The performance approach is encouraged in England and Wales through the application of the authoritative design guidance for fire safety design [6]. However, the guidance does contain elements of the prescriptive approach to the specification of the component systems of fire safety. In Scotland the Technical Standards [7] specify the performance expectations for some aspects of fire safety, they provide intentional statements for other aspects and state specific dimensions for components of fire safety such as travel distance. An example of an intentional statement is: “every building shall be so constructed that, for a reasonable period [of time], in the event of a fire the spread of fire and smoke within the building is inhibited”. There is no other guidance on the specific threat of smoke movement.

LEVELS OF PRACTICE

A "framework for practice" for fire engineering is needed so that the different approaches to the provision of fire safety can be related to each other. The levels of practice of fire safety need to be defined and each fire safety engineer would then be able to define, through self assessment, his, or her, capabilities in each of the twenty-four component topics [3] of fire engineering for professional competence. Five types of practice can be described and each type is appropriate for application to some type of problem, or indeed a combination of levels of application may be appropriate in a single building. These levels are:

1 descriptive, experiential - hunches and the content of guides

2 application of codified experience - the BSI codes, and others

3 compensatory engineering -alternative components; alternative packages; trade - off.

4 quantitative analysis -beginning with the probability of fire occurring and ending with for example, the pipe network design of a sprinkler system.

5 the use of computer modelling and/or simulation - a growing trend.

To arrive at a perfect solution for the fire safety systems required in a building the level of expertise required in the design of a specific set of fire safety systems may range over each of the levels. Some comments on each of the levels will clarify some of the application limitations for the several levels.

1 Over many decades the experience of fires in buildings has accumulated and some of the accumulated wisdom has been collected and published. Such documents are valuable resources and lead to an understanding of the fire phenomenon. This learning through accumulated experience will be supplemented by experience on the fire ground. People who posses a knowledge of fire safety through these mechanisms are able to identify potential hazards and to recommend appropriate traditional fire safety solutions to the identified problems. This approach has been criticised because of the likely over specification of the safety measures. This may be due to the fact that few attempts have been made to disassociate the components and performance specifications for life safety and those for property protection. Now it is much more common to elicit the priority that should be given to the safeguarding of people, the occupants of the building; the valuable contents of the building; and the fabric of the building. The emphasis, or relative values, places on these three vulnerable parts of a building make a major difference to the performance requirement for some of the systems. For example, a smoke extract system for life safety may need to extract 4 times the quantity that would be required for a system that enhances the fire fighting activity. This difference emphasises the fact that the interaction of smoke and ordinary people is a very sensitive issue but the smoke with the fire fighter is not as sensitive due to the equipment and training of the fire fighter. The development and publication of practical guidance is an important part of the experiential approach [4].

2 The application of codified experience has a major impact on fire safety design. The codification of manufacturing information, system performance and the design parameters for the design of the system occurs in the standards making process. In many countries standards bodies such as the British Standards Institution produce design codes by the consensus of the people who populate the technical committees. All of this activity confirms that the published guidance is founded on practicability and not solely on theory but quantitative, analytical design solutions may be included [8].

3 Compensatory engineering is a simple conceptual skill that is supported by all of the available design procedures. An innovative architectural design or the identification of a necessary component of fire safety that is not to be installed causes an important question to be asked. What functions would be performed by the fire safety components that are to be left out of the building? For example, a compartment floor is separating two volumes within a building each being the limit is size that

would be acceptable according to the legislative requirements. It is decided that the spatial design solution would be to remove part of the compartment floor. If part of the floor is removed then it is clear that some of the functions of the floor will need to be replaced using components of fire safety technology that would not be required in the building had the floor been complete. The main fire safety function of a compartment floor is to stop the flow of smoke, gas and flame between compartments. To achieve this functional performance without the solid floor a could mean smoke detector activated shutters. An alternative would be to install a sprinkler system and a smoke control system. These two fire safety functions would be fulfilled by the floor. It should be noted that the omission of parts of the floors enables control of the thermal environment using passive air displacement but some of the interactive consequences are the fire control system and the smoke control system.

4 The quantitative analysis approach includes the application of the fire engineering and mathematical techniques that have been developed and applied to the solution of one set of problems. This is the approach that is enabled through the application of the engineering draft for development [3]. This begins with the probabilistic definition of the likelihood of a fire beginning, then the growth rate of the fire, and the maximum size of the fire in the specific geometry of a single space. At present there are gaps in the probabilistic approach because of the scarcity of reliable data in some aspects of fire safety. In the guide to the application of the principles of fire engineering to buildings the Part 2 contains information n the limits of application of the many mathematical equations in Part 2 of the standard. Fortunately, many of the mathematical expressions have been derived from real, experimental fires so they may be relevant for application within definable limits but they are in no manner appropriate for universal application.

5 The use of computer models to gain answers to complex engineering problems is becoming commonplace. This approach is used in fire safety engineering also. The generation of appropriate models is very time consuming and the more complex models that use the same concepts as are used in fluid dynamics take many hours to run to achieve one result. One of the principal problems is the lack of verification through the use of full scale model or real buildings. Although computer programs are helping in the identification of research programmes the engineering output is regarded as a very useful indicator of the problems to be solved. The most exciting topics that are being analysed are the movement of people to escape routes and the flow of smoke around spaces. The applications of virtual reality techniques has begun and very powerful statements ca be made with virtual reality systems. So far animation has not been used widely but there is a strong likelihood that more interactive experiences will be developed to stand alongside the video compact disks that are available.

INTERFACES, INTERACTIONS AND OPERATIONAL SEQUENCES

An attempt to define the interactive sequence of the systems that are to be installed will be valuable assessment of real performance of the total fire safety system.
The objective of the following list is to emphasise the relationship between the systems in the building is so that the control implications can be identified and solved. The following list is an example of the sequences for a new 7 storey building that is part completed.

Smoke detection/break glass call point in an "open" office floor
Smoke curtains drop in all parts of the building but except for a 7 metre long section near to the fire to allow the smoke to flow into the atrium.
Air extract to the building stopped.
Air supply reduced but maintained.
Toilet ventilation systems not changed
Warning system initiated (simultaneous evacuation) throughout total building.
Bells and /or a voice evacuation system.
Windows/louvres for replacement air in principal, activate automatically
Atrium extract fans (4) operate.
Security and fire wardens perform duties.
Automatic call to the fire brigade
Emergency lighting (maintained) and EXIT signs illuminated already.
Non-maintained emergency lighting operates
Any locked doors in escape routes unlock automatically.
Security ready to receive fire brigade with knowledge of locations of fire.
Sprinklers operate, additional indicator/warning devices activate.
Access to sprinkler control valves needed, location shown at repeater panels and main panel.
Reporting of fire wardens – location(s), procedure, technique.
Fire brigade search pattern.
Re-start procedures for air handling systems
Operation of "auto/on/off" control for atrium fans – implications on systems
Control of raising curtains
Monitoring of flow of sprinkler water.

The sequence outlined above will need to be considered for each different location of fire detection and/or discovery (activation of break glass call point)

CONCLUDING REMARKS

The practice of fire engineering has begun to change towards a numerical approach. In some aspects this is not practicable as not enough is known about the performance of systems except that "it works" so why change? Performance based codes of practice are beginning to be published and the mathematical procedures are being developed also. The interactions between the components of fire safety are essential learning. The interactions with the day to day systems in the building are defined by the synergism generated by the systems. There is no doubt that the closer the relationships the better the total system.

The responsibility for ensuring that fire safety standards in the workplace are maintained will, in the UK, be devolved to the owners of the building. A useful guide on the fire safety responsibilities of being an owner has been published recently [10].

There is no doubt that the interaction of the environment of the workplace and the fire safety features of the building are important. These include the colour of the surfaces of the workspace and the design of acoustic and visual emergency signals.
Interactive sequences of the components of fire safety technology are essential for the full understanding of the actions that need to be programmed into the intelligent building.

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