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Non vi è nulla al mondo paragonabile
alla devozione di una moglie.
Nothing compare to the devotion of a wife

Oscar Wilde

Ogni nostra cognizione principia dai sentimenti
Our knowledge is born with feelings

Leonardo da Vinci

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PREFACE

Dear attendees,

it is a great pleasure to welcome you in Rome in conjunction with the conference "*Integrating Historic Preservation with Security, Fire Protection, Life Safety and Building Management System*".

The conference, sponsored by the Italian "Ministero Dell'Interno", that has the responsibility for managing the Fire Brigade Service, and the National Fire Protection Association - USA, aims at focusing the attention on the safety and security problems of Historical Buildings and Cultural Resources.

Historical Buildings and Cultural Resources represent a unique and sole patrimony for the whole humanity, pieces of history and art masterpieces which are not reproducible and which can be damaged and lost for ever.

The Cultural Resources are representing also a real patrimony and business opportunity, so that today the necessity both of preserving the business and of assuring the safety of the visitors is growing.

During the last decades, because of quite a lot of social modifications and politic events, we lost several unique pieces of our History around the World; nowadays all of the Historical Buildings and Cultural Resources should be listed as "sensitive targets" representing specifics safety and security problems.

The panel of experts, speaking at the conference, would like to offer to the World Citizens the opportunity to discuss and focus the attention on the new safety and security approach, allowed by the introduction of new engineering concepts and more efficient technologies, that, if applied, will minimize, contain or even avoid damages and prevent life losses.

See you in Rome,

PROTECTION AND PREVENTION PRINCIPLES IN THE FIELD OF CULTURAL HERITAGE

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ABSTRACT

This paper analyses all problems concerning heritage preservation and protection against environmental and anthropogenic risks. Relevant Italian legislation based on the recommendations of the Council of Europe is also reported. The concept of safety is examined from the perspective of cultural assets and harmful activities. Special attention is drawn to current fire safety regulations and innovations in exhibition management in museums. Finally, the concept of "safety plan" is explained, i.e. the most important tool to ensure risk mitigation and the adoption of appropriate measures to reduce the likelihood and the seriousness of harmful human activities and natural forces.

The particular nature of works of art and buildings containing them represent the starting point for developing appropriate measures for reducing the risk detected from a specific analysis. It must be stressed that it is often helpful to define more precisely the utilisation of spaces to improve safety conditions of exhibits and to increase their protection.

1. OBSERVATIONS ON PRESERVATION

Our country's national heritage is extremely diversified both in term of the materials and techniques applied. Their preservation implies action both against their natural degradation and harmful human activities. However, all necessary precautions may not totally remove the effect of time: in fact, the account of archaeological discoveries and works of art stored inside museums or other places is characterised by restoration works which, even when correctly carried out, always involve the loss of particles (even small) of the historic document. Therefore, all efforts must be made to minimise the necessity for such restoration works and ensure, at the same time, their preservation and public enjoyment. Among the factors responsible for the loss or degradation of works of art are included catastrophic events, such as fires and thefts, as well as environmental conditions existing in structures where the heritage has been stored or exhibited.

Literature on heritage preservation directs the attention of museum planners and managers to the noxious effects caused by electromagnetic radiation, humidity, temperature and air pollution. The incident electromagnetic radiation gives way to colour changes and activates dangerous chemical reactions. Organic materials are more vulnerable to these, but also inert materials, like pottery and glass, are affected by them. Besides chemical effects, incident electromagnetic radiation causes changes in superficial temperatures, giving way to mechanical dilatation and contraction. Levels of danger are the result of both radiation wave length and absorbed quantity. In order to determine the absolute quantity of absorbed radiation, it is necessary to measure flux quantity and exposition time; on the basis of these two factors parameters are defined which enable adequate exhibits preservation.

The main hygrometric factors affecting preservation are air temperature and humidity surrounding the object, as well as the gradient relative to these two parameters.

Furthermore, air quality affects preservation according to solid and gaseous pollutants concentration. On the one hand powders lay on the surface of works of art and their removal requires abrasion, on the other hand powder particles in the presence of humidity may activate chemically or contain fungus spores or bacteria or insect eggs which may give way to an organic attack. Among gaseous pollutants sulphur dioxide and sulphuric acid are classified as acid pollutants together with nitrogen dioxide which becomes nitric acid in the presence of water.

Ozone is an oxidising pollutant which causes damages due to the combination of oxygen with other materials. Both pollutant classes have noxious effects on almost all exhibits, but oxidising pollutants are more dangerous for organic materials.

Thus, to ensure preservation it is necessary :

- to minimise the incident electromagnetic radiation and the absorbed dose, i.e. a less intense lighting and a shorter exposition time;
- to stabilise hygrometric conditions of air to avoid sudden changes in temperature and humidity and maintain a balance between work of art and environment;
- to achieve an high purity level of air surrounding the object.

After having ensured suitable preservation, it is necessary to consider the risk connected with catastrophic events or criminal acts, such as vandalism or thefts. It is possible to assess catastrophic events like fires or explosions, with relevant possible ignition causes (free flame, short circuit, lightning, etc.) and presence of combustible or explosive materials in the structure (cleaning agents, restoration materials, etc.).

Together with exhibit safety, consideration must be given public enjoyment. Consequently, safety measures must provide adequate visibility of the exhibit and its enjoyment. Moreover, it is necessary to ensure public safety, a comfortable visit and good working conditions for museum operators.

In exhibition areas, preservation needs (e.g. soft lighting, low humidity and temperature, protection against dust or corrosive agents) often clash with visitors' enjoyment of the exhibition (proximity to the exhibit, adequate visibility, etc.).

The situation within storage facilities is different because human presence is limited and the absence of the public allows for optimal preservation conditions.

Following these observations, some solutions can be developed able to ensure both safety and preservation requirements, by means of fixed protection systems or exhibition rotation programmes. These programmes allow exhibits to be placed for a period in storage where a strictly controlled environment reduces the cumulative effect of noxious factors to which they have been exposed. In Nov. 1993 the Council of Europe passed a Recommendation of the Council of Ministers concerning the protection of cultural heritage against natural catastrophes and a second one concerning its protection against illicit acts.

The Italian Official Journal n° 52, dated March 4, 1993, published the Ministerial Decree n° 569, dated May 20, 1992: "Regulations concerning fire safety standards for historic and artistic buildings designed to serve as museums, art galleries, exhibition areas". The Presidential Decree n° 418 of June 30, 1995 "Regulations concerning fire safety standards for historic artistic buildings serving as libraries and archives" was published in the Official Journal n° 235, dated Oct. 7 1995. Then in 1999 the Decree n° 490 followed, containing all legal provisions relating to cultural heritage. Finally, in 2001 the Ministerial Decree "Guidelines on scientific and technical criteria and development and operation standards for museums" was published.

These rules represent legislation in Italy relating to the preservation, safety and enjoyment criteria for national heritage in public museums.

However, it must be said that most portable cultural heritage are not placed in structures designed for this purpose. Therefore, it is necessary to analyse problems according to the particular site involved: museums or open areas, churches or private/public buildings.
In case of museums or exhibitions the "display" of exhibits has to be planned in order to achieve high protection levels and proper personnel are employed to protect them. In relation to churches and other buildings no "display" of exhibits is usually involved, but their design

depends on their purpose: either liturgical or non liturgical activities. Therefore, in these situations, it is more difficult to plan protective and risk reduction measures and the protection of objects is not the priority task of surveillance personnel (for instance sacristans or porters in residential structures, etc.).
The problem of preserving assets in diocesan museums or in churches is particularly difficult to solve, considering the large quantity of works of art present in such structures and the small number of people available for their effective protection.

In all cases, one of the most important factors in risk reduction is the responsiveness of the relevant personnel. This ability is enhanced through training and information on operational procedures. It is worth noting that the emergency response will be carried out under psychological stress, therefore appropriate training allows personnel to develop quick response to a crisis ensuring correct implementation of planned measures.

Ministerial Decree n° 569 of 1992 provides fire safety rules for museums and permanent exhibitions (with no cultic purposes), but when located inside historic and artistic buildings alternative measures must be adopted.

When the museum, the "container" itself, has to be preserved (because it is an historic or artistic building), the relative risk analysis must be greater than usual, since it has to face also the problems of preserving the value and structure of the building.

In churches and other buildings used for cultic activities the arrangement of furniture and the room dimensions are critical factors, as is the practice of lighting votive candles, which represent a particular fire hazard. Sometimes in these buildings electric and safety systems have been installed in inaccessible positions or close to combustible materials.

In such buildings the fire extinguishing system must comply with a set of restraints concerning both the structures and the exhibits these contain:

- to protect works of art it is necessary to choose a compatible extinguishing agent;
- to protect the structure it is necessary to take into account that internal space is very large and cannot be divided into compartments, door and window frames do not always close perfectly tight and it is difficult to install an extinguishing gas system inside the rooms;
- another problem is represented by the type of people present inside these buildings (aged people, etc.) and by the number and the ability of operators (often older volunteers, with no training);
- the positioning of fire detectors (for the automatic activation of extinguishing systems) depends on the decor used in the affected rooms, while manual activation is often not feasible due to the qualifications of employed personnel;
- however, some alternative measures can be planned and implemented, within the liturgical setting, such as room surveillance and disconnection of all electric systems at the end of opening hours, the concentration of candles in a single monitored area, the updating of electric systems and the installation of atmospheric charge protection systems.

In buildings destined for permanent exhibition most problems depend on the very nature of the structures concerned. For instance, the installation of heating and air conditioning systems at the National Gallery of Umbria, in Perugia, or the Cherubini Institute, in Florence, where boilers were placed in spare rooms, crowding unsuitable spaces.

Similar problems concern the construction of emergency exits which before the enactment of Ministerial Decree n° 569/92 were built in all buildings, whereas now it is possible to integrate or replace them with other measures aimed at reducing the overcrowding of rooms.

Special attention must be paid to the risk deriving from restoration works. The above mentioned Decree n° 569 provides rules for building sites inside museum complexes, but the risk is still present, as shown by the fire in the Chapel of the Holy Shroud in Turin and by the construction site in the courtyard of Palazzo Pitti in Florence.

Cultural heritage safety is directly related to the risk involved and the most appropriate practice to adopt is risk assessment. This means identifying the risk (theft, fire, criminal acts, flood, etc.), examining its frequency of occurrence (likelihood) and the possible consequences for the subject to be protected (expected damage). The analysis of these factors identifies the magnitude of the risk for that property. On the basis of risk analysis, mitigation measures can be developed, and the likelihood of occurrence of the event and consequences flowing therefrom can be reduced, even if not completely removed. The study of all steps necessary to reduce the risk is called "safety project", and this activity is provided for in the most recent regulations.
The decision to define the risk analysis methodology based on the characteristics of the cultural assets to be protected, both material assets (like a book or a library) and immaterial assets (such as workers' health) in the context the subject activity is involved, transfers the responsibility for achieved safety levels on both safety planners and museum management/control authorities. Earlier technical standards solved safety problems with a series of requirements that, once met, ensured an acceptable level of safety and made planners and operators less responsible for possible harmful situations. Now the responsibility for damage to cultural assets can be placed on a doubtful project choice, or inadequate control/inspection system or poor management.
Within this framework, a safety project for cultural heritage can be extremely complex but mandatory, because there are further aspects which come into plat besides the expected ones:

- the necessity to protect property which is valuable not only from an economic point of view, but also from a cultural one;
- the exhibition of works of art in buildings of remarkable cultural interest which, therefore, cannot be modified/altered and are designed for different purposes;
- the presence of works of art with a significant symbolic value, which might be the object of criminal acts.

These aspects affect deeply the safety project planning since this involves not only the protection of people in case of harmful activities, but also the protection of property, with no possibility of structural change. Therefore, there must be a close co-operation between safety planners and the experts managing the activity. The project options must comply with conservation needs and the needs of the public; that's why the person charged with exhibits preservation and museum operators must be aware of the decisions taken by the planner and help him/her by offering suggestions for the preservation and protection of valuable historic and cultural heritage.

A safety culture must become part of the cultural background of preservation experts, although they are not required to have the professional skills necessary to develop a safety plan.

2. INNOVATION ELEMENTS IN CURRENT FIRE PREVENTION LEGISLATION

In 1993 the Minister for Cultural and Environmental Heritage and the Minister of the Interior issued jointly a new regulation (D.M. n° 569, May 20, 1992). These new provisions of law seemed at first to reduce the safety level for the public, but in reality they facilitated public egress by providing alternative solutions. As well, the new regulation limits the use of devices which might be ignition sources, prohibits the storage of flammable and explosive substances, regulates electric systems and makes the installation of atmospheric charges protection systems mandatory. It contains a list of materials allowed for new furniture or decor, and requires new boilers to be sited outside the building. Since it is impossible to completely remove all risks, this regulation provides for the installation of extinguishing devices and systems, defining and upgrading them according to room occupancy and museum personnel activities.

Regulation Title III is extremely innovative since it contains management provisions. In this chapter two new subjects are introduced: the person responsible for the management of the museum (museum director) and the person responsible for technical safety. By listing their different duties and responsibilities, the regulation introduces new management principles: it establishes that all systems must be regularly checked and relative inspections recorded in a logbook and that all services must always be adequately manned by qualified personnel, capable of using fire alarm and extinguishing equipment. Museum personnel must be trained also in evacuation procedures. Art. 11 provides for the development of emergency plans, which must contain instructions for the mandatory familiarisation of museum personnel with these.

The new regulation is based on the concept that a museum is a complex organism, composed of manifold, often unchangeable elements, which have to interact to ensure a safety level higher than in ordinary public buildings. In the case of museums, heritage preservation and safeguard has the same priority as human life safeguards.

The new regulation presents also the concept of intervention plan, a new element which is present, although in a different form in both the Recommendation of the Council of Europe and in the Italian "Health and Safety at Work" Act (Decree n°626, Sept. 19, 1994). The protection activity aims at developing prevention measures able to prevent harmful activities, and mitigation measures, to reduce their negative impact.

Preventive measures can be represented by:

- organisational measures
- mechanical protection
- electronic detection
- human surveillance

Mitigation measures can be:

- emergency plans (operational and organisational ones)
- evacuation plans (for visitors and exhibits)

3. SAFETY PLAN

A safety plan is the main tool able to ensure the reduction of risks and the development of measures to mitigate the harmful activity effects. While risk analysis is carried out in consideration of different risk types, the safety plan developed provides a synthesis of all data collected through the specific analysis. For example, protection against thefts can be provided by a system which limits the access and circulation of visitors in and to the exhibition area, but this creates problems both for people evacuation and for the enjoyment of the exhibits by the public. Only a comprehensive project can take into account all variables affecting different aspects of safety.

Another element is the new definition of space allocation to different activities: offices, exhibitions, archives, storage facilities and laboratories. This would allow museum management to profit from more favourable environmental conditions without using mechanical devices: e.g. sensitive materials might be stored in internal rooms where environmental parameters do not change in time, and moving other activities to other rooms.

A smoke detection system is essential and must be connected with a manned control room. The most usual systems detect combustion products present inside the building; smoke detectors are usually visual or fitted with a ionisation chamber. The latter is based on the conductivity variation of ionised air in the presence of combustion particles. Visual systems are based on the reflection of ultrared radiation caused by the mentioned particles. Fire detection capacity depends on the sensitivity of detectors and it changes according to the diameter of released particles.

Devices must comply with test requirements of Presidential Decree n° 246/93 and installations must be in compliance with standards provided in UNI 9795 CNVVF CPAI Regulations "Automatic fixed installations for detecting and reporting fires". Fire detection systems do not require special protection against sabotage on both detectors and alarm connections, but it is sufficient to use failure proof circuits (ring systems, emergency circuits, etc.) and these systems can be operated with no problems when the building is open or closed to the public. Only areas where free flames are allowed may present a risk, but this activity can be prohibited when the museum is open.

A third category of risk includes the structure itself and the activities which take place in it. Fires, collapses and structural damage are often caused or facilitated by the very nature of the building. I refer for instance to paintings or statues stored in rooms with floors ruined by woodworms which may damage the works of art, or to the risk of leakage from liquids from roofs or pipelines. Also in this case the plan, after analysing the risk, has to develop all measures appropriate for the prevention of the harmful activity or for the mitigation of its effects.
Safety plan is composed of a series of active and passive protection measures and by a group of management provisions for both emergency and follow-up operations. Obviously, personnel must be informed and trained to carry out such operations. Information and training are two fundamental elements of a safety project.

The safety project, therefore, can be divided into the following phases:

a) risk identification, that is the definition of risks which are likely to affect the assets. Risks can be divided into specific risks for books (connected with reading), risks due to the particular nature of the building and risks caused by building location;

b) identification of major hazards, depending on activities carried out in the building and neighbouring structures;

c) risk analysis, the assessment of occurrence likelihood of each event and possible consequences;

d) definition of non compatible risk, i.e. when the risk mitigation is necessary and when it is required by law;

e) planning of a safety project, which must include physical, operational and organisational measures for mitigating the risk;

f) emergency management plan, which contains all measures necessary to limit the negative consequences of harmful activities and identifies operators and operations involved in cases of emergency;

g) development of a maintenance logbook, reporting plans of safety systems, proper operation and maintenance rules, as well as frequency of inspections and revisions;

h) programme for personnel information and training, defining not only information and training procedures, but also frequency of tests and drills;

i) identification of responsible people, with indication of their responsibilities during ordinary and extraordinary management, their competency and duties, as well as the identification of competent authorities for check implementation and of relative time schedules and procedures. (One might develop a 'sanction' system for non-performing workers and a 'reward' plan for workers who contribute in enhancing safety level by useful suggestions or activities, similarly to what is provided for in Decree n° 626).

On the basis of this logical process involved in the "safety project", it may be possible to simplify the sequence of these phases and to adjust these to different operational situations, inserting in each phase the actual requirements of the affected subject.

LIBRARIES AND MUSEUMS SANITATION AND FIRE SAFETY INTERACTION: STATE OF THE ART

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ABSTRACT

One of the most persistent causes of loss of cultural property and museum collections is damage done by insects, fungi and bacteria. Recently considerable research has been conducted with the use of modified atmospheres to manage insect pests, as a direct replacement for fumigation with toxic fumigants. Until relatively recently, the idea of putting a museum artifact in a low oxygen or anoxic atmospheres was not taken very seriously, mostly because of the difficulty of creating and mantaining such an environment. Today, creating an anoxic microenvironment is very simple and safe because of its lack of toxicity to people and collections, consequently anoxia is becoming the method of choice for treating infested objects in museums. A new R&D area could be the designing of an integrated system, which works both as a fixed fire-extinguishing system and as a sanitation one.

Keywords: insects, museum, library, sanitation, anoxic treatment, inert gas

1. INTRODUCTION

One of the most persistent causes of loss of cultural property and museum collections is damage done by insects, fungi and bacteria.

Main targets are manuscripts on paper and parchment, natural history collections and herbaria, but massive wooden objects also are often attacked and, occasionally, seriously harmed.

Fungal and bacterial attacks on historic objects can result in unsightly blotches ranging from whitish through green or reddish brown to black, as well as actual destruction of the fine structures of their surfaces [1].

In the early 1980s, a number of trends emerged in museum pest management and the concept of *Integrated Pest Management* (IPM) was introduced. In fact, while there was concern about the damage that insects, fungi or bacteria were doing to different kinds of collections, there was equally concern about the damage that pesticides might do to the same collections and to the operators.

An IPM plan include monitoring and identification of the pest, inspection, habitat modification, good sanitation, treatment action and evaluation. IPM aims to prevent pest problems from occurring, reducing the use of toxic materials that may adversely affect the environment and protecting materials from pests [2].

2. TREATMENTS

2.1 FUMIGANTS

In the past, fumigation was seen as the sole means of ensuring elimination of pest infestations. The use of fumigants involves exposing infected material to a lethal gas; fumigants are among the most toxic of pesticides.

Fumigant gases remain in the air and can easily spread over a wide area.

In general, fumigants and other pesticides can cause long- and short-term health problems, ranging from nausea and headaches to respiratory problems or cancer. Many chemical treatments might not be harmful at the time of exposure, however they might be absorbed from the body causing health problems years later. It's also known that many of the chemicals damage the treated materials and no chemical treatment provide a residual effect that will prevent re-infestation [3].

Ethylene oxide, a gaseous fumigant, was commonly used in libraries and archives until the 1980s, being effective against insect adults and larvae but not in killing eggs unless used in vacuum. Unfortunately, it poses serious health hazards to workers and can change the physical and chemical properties of library and museum objects, such as paper, parchment and especially those materials with a high fat content (e.g. leather).

Governments have lowered acceptable limits on ethylene oxide exposure (OSHA -Occupational Safety and Health Administration - Permissible Exposure Limit is 1 ppm as an 8-hour time-weighted average over an 8-hour day and a Short-term Exposure Limit of 10 ppm averaged over a 15 minute period) and most existing ethylene oxide chambers in libraries cannot meet these restrictions.

Sometimes **methyl bromide** is used instead of ethylene oxide, but even a little quantity is highly toxic. Methyl bromide is a highly effective fumigant used to control insects, nematodes, weeds and pathogens.

The **sulphuryl fluoride** (the commercial name is Vikane) is used to fumigate wood and timber structures. It penetrates deeply into the woods and often thoroughly eliminates the pests. Research has been undertaken to assess the potential damage of Vikane to modern and traditional resins and waxes pigments, as well as metal and the potential interaction with proteins and dyes. Little to no visible damage to materials was noted when Vikane was properly applied [3,4].

2.2 Freezing

Insect pests in museums may be eradicated by freezing as an alternative to the use of fumigants and pesticides. Freezing kills insects by rapid temperature change.

Controlled freezing has been applied in various institutions over the past 15 years and its effectiveness has been considered largely favourable.

Freezing is attractive because it involves no chemicals and poses no hazard to library staff and environment. It can be used on most library materials and does not appear to damage collections, but research into this question is not yet complete (very fragile objects should probaby not be frozen). Items have to be bagged and sealed to prevent insects from escaping. Bagging protects objects from changes in moisture content during defrost cycles and from condensation on cold books, when they are removed from the freezer.

It's essential to guard against freeze resistance: some insects can acclimate to cold temperatures, if they are kept in a cool area before freezing or if freezing happens too slowly.

To avoid damage from the freezing process, specimens must be sealed in polyethylene bags at room temperature, cooled steadily to –20°C and held at this temperature for at least 48 hours. The bag must not be opened until the contents have thawed to room temperature (at least 24 hours). Repeated freeze-thaw cycles are recommended to assure insect eradication [3,5].

2.3 HEATING

Heat can effectively exterminate insects and may be efficaceous in killing some moulds, but it should not be used for the sanification of paper collections because of accelerated oxidation and ageing. Heat causes other problems, such as softening of waxes, synthetic adhesive and surface coating, direct expansion of brittle material such as glass, shrinkage of animal skins in leather-bound books [3,5].

2.4 GAMMA RADIATION

Gamma radiation can be effective against insects, but the minimum lethal dose for various species is still unknown and is affected by variables such as climate conditions and the nature of the infested material. Most important, research has shown that gamma radiation may initiate oxidation and cause scission of cellulose molecules and has the potential to damage seriously paper-based materials [3].

2.5 MICROWAVES

Microwaves have been used for rapid treatment of books, papers and herbarium specimens, but there can be undesirable side effects as the heating may be uneven and localized overheating may occur. In addition, unnoticed metallic objects such as paperclips may cause sparking and ignition of specimens and paper. This technique is not considered safe for use with museum collections [5].

2.6 MODIFIED ATMOSPHERE

Recently considerable research has been conducted with the use of modified atmospheres to manage insect pests, as a direct replacement for fumigation with toxic fumigants.

Until relatively recently, the idea of putting a museum artifact in a low oxygen or anoxic atmospheres was not taken very seriously, above all because of the difficulty of creating and mantaining such an environment.

Today, creating an anoxic microenvironment is remarkably simple and therefore, anoxia is becoming the method of choice for treating infested objects in museums mainly because of its lack of toxicity to people and collections [5,6,7].

Mechanisms of insect mortality

A number of mechanisms have been proposed to show how anoxia causes increased mortality, but desiccation seems to offer the best explanation; in fact:

?? insect physiology provides a well defined respiratory system that leads to accelerated desiccation in the absence of oxygen or in the presence of modest amounts of carbon dioxide;

?? death rates generally increase with dehydration; increasing temperature or decreasing humidity tipically makes anoxia a more effective killing procedure;

?? mortality rates are positively associated with weight loss, which under anoxic conditions can occur only by loss of water.

Insects are able to control both the exchange of oxygen and carbon dioxide and the conservation of water by a series of orifices known as spiracles.

The spiracles are normally kept closed to minimize water loss and are opened just enough for the insect to take in needed oxygen. When oxygen is scarce, they are forced to open more frequently and widely, thus causing dehydratation. An insect must get rid of carbon dioxide as well and high concentrations of this gas in modified atmospheres, quickly sensed when the spiracles are opened, will also lead to sustained opening and, consequently, dehydration.

These two conditions, that is very low oxygen levels and high concentrations of carbon dioxide, force the spiracles to open and remain open. This unnatural condition leads to high rates of water loss, as much as seven to ten times higher than when the spiracles are closed.

Rising temperatures increase insect respiration, resulting in a greater production and loss of water and this is demonstrated by the research work of Valentìn (1993) (see Fig. 1 and 2).

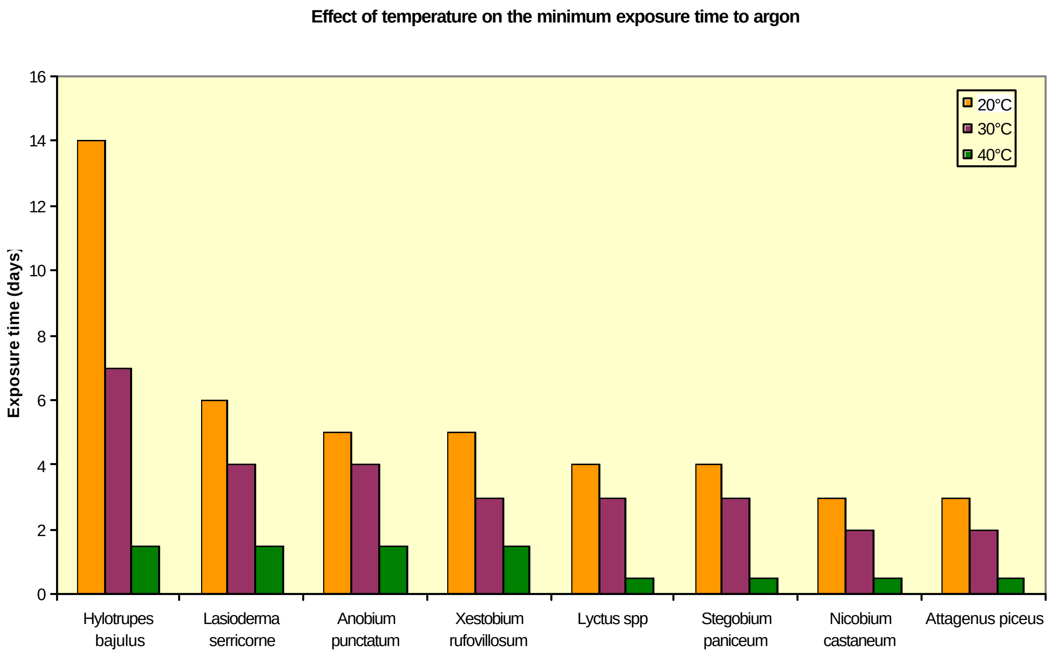

Fig. 1: Effect of temperature on the minimum esposure time to argon required to achieve complete insect mortality at 40% RH and 300 ppm oxygen (Valentìn, 1993).

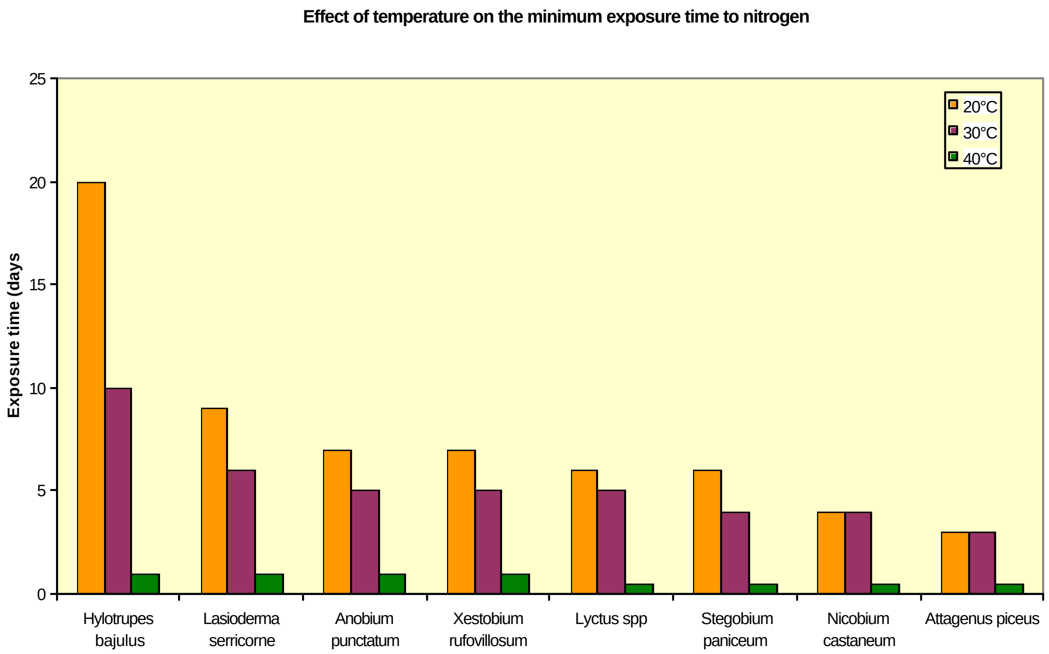

Fig. 2: Effect of temperature on the minimum esposure time to nitrogen required to achieve complete insect mortality at 40% RH and 300 ppm oxygen (Valentìn, 1993).

As you can observe from Figg. 1-2, for each carrier an increase in temperature from 20 to 30°C decreases the exposure time approximatly 30% and an increase from 20 to 40°C shortens the exposure time about 90%. Furthermore, under comparable conditions (in the specific case, 40% RH, 300 ppm oxygen at 20°C, 30°C and 40°C), it generally took**s** 50% longer with nitrogen than with argon to reach 100% mortality.

Ali Niazee (1972) observed that helium also provides a much faster kill than nitrogen; the researcher found that helium generally took only half as long as nitrogen to achieve 97% mortality with red flour beetles and confused flour beetles (see Table 1).

Table 1: Effect of temperature and inert gase type on the exposure time required to produce 97% insect mortality at 38% RH and 0.05% oxygen concentration (AliNiazee, 1972).

	Temperature		
	15.6°C	21.1°C	26.7°C
Confused flour beetle			
Helium	12 h	9 h	5 h
Nitrogen	30 h	15 h	12 h
Red flour beetle			
Helium	12 h	9 h	6 h
Nitrogen	24 h	13.5 h	12 h

Jay, Arbogast and Pearman, instead, studied the relationship between mortality and RH, by examining the death rate of red flour beetles and confused flour beetles in nitrogen atmosphere, containing between 8000 ppm and 10000 ppm oxygen after 24 hours at relative humidities of 9%, 33%, 54% and 68%. As shown in Fig. 3, both species showed a marked increase in mortality as the RH decreased.

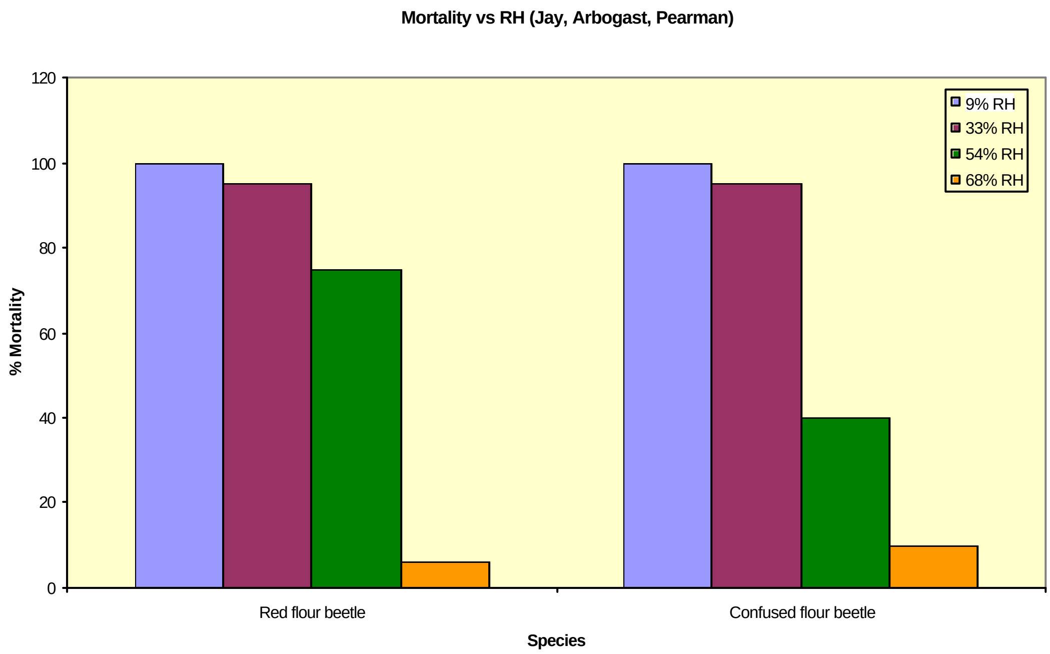

Fig. 3: Mortality of red and confused flour beetles exposed 24 hours at 26°C to 1% oxygen in nitrogen at different relative humidities (Jay, Arbogast and Pearman, 1971).

Under anoxic conditions, any decrease in weight is due almost entirely to loss of water; when total body-water loss approaches 30%, most insects die.

Donahaye's research was concerned about the developing of resistance of insect species to modified atmosphere. For this purpose, he subjected some red flour beetles to two modified atmospheres, that is 0.5% oxygen in nitrogen and 20% oxygen and 15% nitrogen in carbon dioxide, at 95% RH until 30?50% remained alive (the extremely high humidity was employed to suppress the desiccation mechanism). He repeated the treatment with the offspring of the survivors for over forty generations and he observed that two resistant strains of beetle developed, each resistant only to the specific atmosphere to which it had been subjected. The type of compensations that enabled the red flour beetles to survive included a decrease in respiration rate, an increase in stored oxygen reserves, physiological changes to prevent water loss and other biochemical adaptations.

Anyway, different studies suggested that evolution toward resistant species occurred when desiccation was overwhelmed by a supply of water. [8].

Common museum pests

Some common museum pests are enumerated in Table 2 [1,8,9].

Table 2: Common museum pests

PESTS	CLIMATE				
	USA	*Columbia*	*Cuba*	*Spain*	*Italy*
Anobium punctatum	+		+	+	+
Anthrenus museorum				+	+
Attagenus piceus	+			+	+
Blattella germanica		+	+	+	+
Catorama sp.			+		+
Crytotermes brevis	+	+	+	+	+
Crytotermes cevifroms		+	+		+
Dermestes lardarius					+
Drosophila melanogaster	+				
Hylotrupes bajulus	+			+	+
Kalotermes flavicollis		+		+	+
Lasioderma serricorne	+		+	+	+
Lepisma saccharina		+	+	+	+
Liposceli divinatorios		+	+	+	+
Lyctus brunneus	+	+		+	+
Lyctus linearis				+	+
Lyctus pubescens				+	+
Neogastrallus sp.			+		+
Nicobium castaneum	+		+	+	+
Periplaneta americana		+	+		
Periplaneta brunnea		+	+	+	+
Reticulitermes sp.		+	+		
Reticulitermes lucifugus				+	+
Stegobium paniceum	+		+	+	+
Tintola sp.		+		+	+
Xestobium rufuvillosum	+			+	+

Proteinaceous material, such as parchment, leather and mummified tissues, are highly susceptible to aerobic fungal and bacterial growth.

Aerobic bacteria can damage both the surfaces and the layers of these materials, as do fungi with their blotches of white, green or dark-coloured colonies.

Anaerobic bacteria, instead, produce proteolytic enzymes, which cause collagen depolymerization and thus the loss of an object's strenght and even its integrity.

Some common aerobic microorganisms are *Aspergillus niger*, *Aspergillus flavus*, *Penicillium commune*, *Actinomyces sp*., *Bacillus sp*., *Streptomyces sp*.

Anaerobic fungi are very infrequent in organic objects [1].

<u>The present-day sanitation technologies using anoxic conditions</u>

An anoxic environment suitable for treatment of infested objects can be achieved through two different basic approaches: static and dynamic.

With the *static procedure*, which is the more common approach, objects are held under high-purity nitrogen or argon in a tightly sealed container with as little transmission of gas as possible. The oxygen concentration is brought down to anoxic levels by one of the three following methods:

?? the container is purged with many exchanges of high purity nitrogen;

?? the oxygen is removed using large quantities of an oxygen absorber;

?? combination of purging and adsorption.

This procedure is used for small objects.

With the *dynamic approach*, an inert gas is continuously passed through the system during the treatment. Oxygen free nitrogen or argon is used to flush all the air out of the container by initially using a high purge rate; then, when an oxygen concentration of less than 1000 ppm is reached, the flow is reduced to that needed to maintain the low oxygen level for the duration of treatment. This procedure is suitable also for bigger objects [1].

At the present, the two following modified atmosphere treatments are used:

?? the *BOOK SAVER*? Process, which has been developed by the spanish CSC (Conservaciòn de Sustratos Celulòsic S.L., Barcelon) center, uses a machine, into which the bound books and documents are introduced, together with eptafluoropropane (HFC227) containing a reagent that neutralizes the acidity without attacking the ink. The amount of reagent to be used and the contact time between the material and the reagent depend on the state of the material to be treated.

?? the *VELOXY*? (VEry Low OXYgen) Process was developed, patented and commercialized in Italy and) Europe by R.G.I. (Resource Group Integrator srl); it's a machinery, which uses the method of anoxia to control the parasites.

3. LIBRARY AND MUSEUMS SANITATION AND FIRE SAFETY INTERACTION

Considering that gas fire-fighting total flooding systems can be used to protect cultural institutions, a new R&D area could be the designing of an integrated system, which enables fire protection and pests control at the same time; there can be no doubt that it might represents a concrete possibility of increasing anoxic tecniques utilization in the control of library, archive and museum pests. Besides, both from performance and from a technological point of view, the most advanced solution should be the installation of a gas system, which extinguishes flames when a fire breaks out and supplies inert gas when a sanification is necessary [10].

In order to realize an integrated system, it is necessary to solve some problems related to:

?? *microclimate conditioning and oxygen concentration control*: as you have seen, the success of an inert gas sanification process is strictly correlated with microclimate (temperature and relative humidity) and oxygen concentration control; consequently it's very important monitoring and controlling these parameters by appropriate instruments, having the right resolution [1,11];

?? *designing of an integrated system with bivalent technical specifications*, that is capability of working both as a fixed fire-fighting system and as a sanitation system; it's necessary to define the technical specifications of the integrated system and to optimize its performances, finding a right compromise among costs, time of exposure and effectiveness of the treatment;

?? *sealing of the space which needs sanification*: the effectiveness of the sanitation treatment depends on the capability of maintenance of both anoxic conditions and optimum temperature and relative humidity values, therefore it is necessary the identification of the best sealing procedures, which garantee both an easy application and removal of the sealant and a minimum damage to the structures;

?? *monitoring and evaluation of the effectiveness of the treatment*, through specific bio-assays, evaluating pest mortality rate.

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The Importance of Certificated Products and Services

Fire & Security Protection with LPCB

Chris Gill

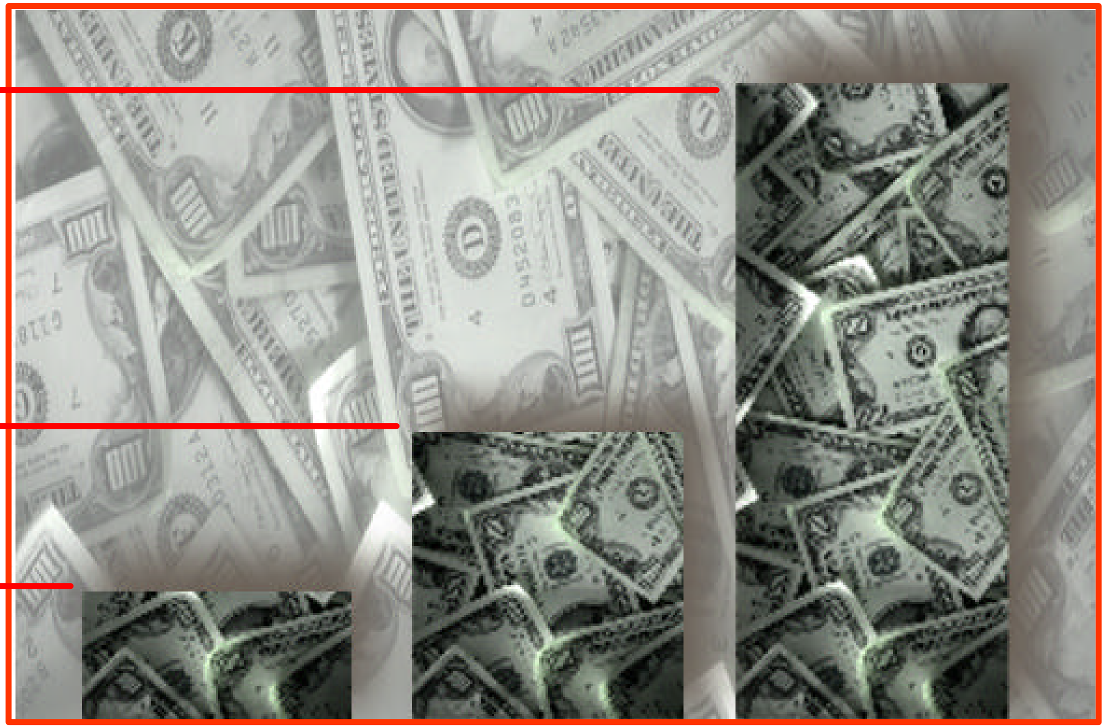
Technical Manager

Purpose of presentation

- What do we do and why?
- The benefits of good products
- The benefits of good installation

Why do we do it?

The cost of fire and theft



Priceless!

$17,000/sec

$1,000,000/hr

Large EDP Facility

Oil Production

Art & Historic Infrastructure

Risk Assessment

What steps can we take to minimise the risk of fire and theft?

Can we rely upon our installations?

- Products
- Installation
- Forthcoming technologies
- Novel or tailored products

Product Testing

V

Certification

Common claims of product compliance

What do the following claims really mean?

- “Complies with …”
- “Designed to …”
- “Tested to …”
- “Certified to ...”
- “Certified by …”

Unfortunately, not everything is always as it seems!

Testing

- Testing should be carried out by a third party, accredited test facility
- Testing is required to:-
  - report product performance
  - to demonstrate compliance to a standard
  - to develop new products or methods
- A test report, reports on the performance during testing - it is a "snap-shot" in time ...

Testing

- Samples tested may not be representative of the product
  - laboratory produced material
  - laboratory produced test samples
  - ‘altered’ assembly methods
- Testing provides facts for evaluation by the report reader
  - which can be misinterpreted
  - like statistics they can be manipulated
  - renewal dates are overlooked or removed

What is certification ?

- **Certification provides third party assurance that a company's claims of:-**
  - performance and manufacturing competence are true
  - <u>continued surveillance and audit testing</u> ensures that they remain true
- **The body providing certification is itself monitored in order to retain its credibility:-**
  - accreditation confirms that we are operating correctly.
  - it is part of our own risk management process
  - it is a requirement for our Notified Body status

BRE Certification - Brands

LPCB -

- Certification of fire and security products and services
- Quality Management Certification (ISO9000)
- Notified Body status (CE Marking)

BRE Certification -

- Certification & Technical Approval of construction products
- Quality Management Certification (ISO9000)

LPCB

Fire & Security protection by good installation

Why have installer Schemes ?

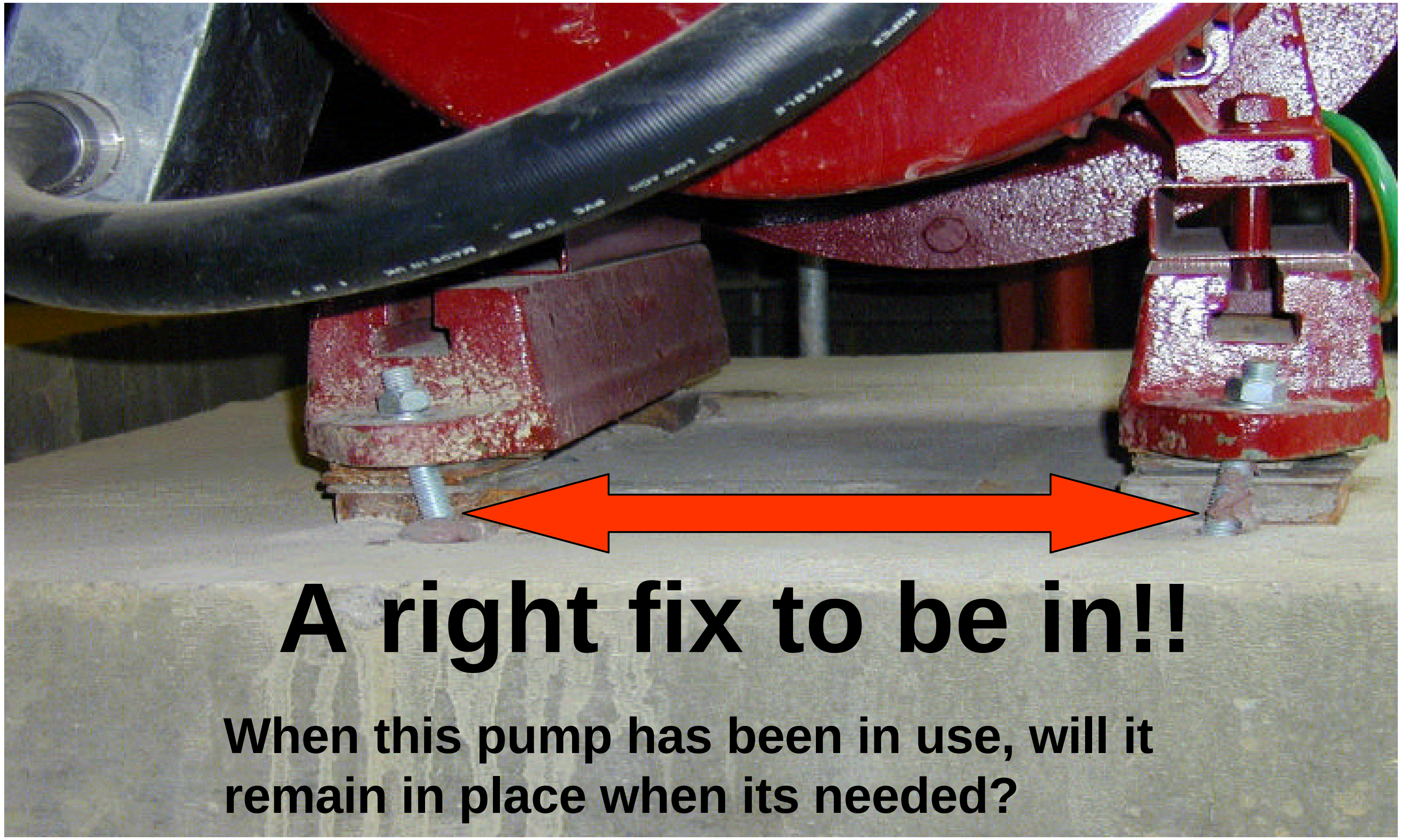
- To ensure that systems are properly designed
- Use reliable equipment
- To maintain and improve standards of installed work
- To ensure systems are properly maintained

Installer assessment process

Assessment process:

- Assess technical capability of Firms to design, install, commission and service systems to accepted design standards
- Review examples of the Firm's designs and inspect a number of sites for compliance.
- Continued (6-monthly) surveillance visits

Uncontrolled Installation



X

The protection = Product + Installation

Not just good products but good installers with:

- Knowledge
- Experience
- Qualifications
- Skills

Conclusion

Conclusion

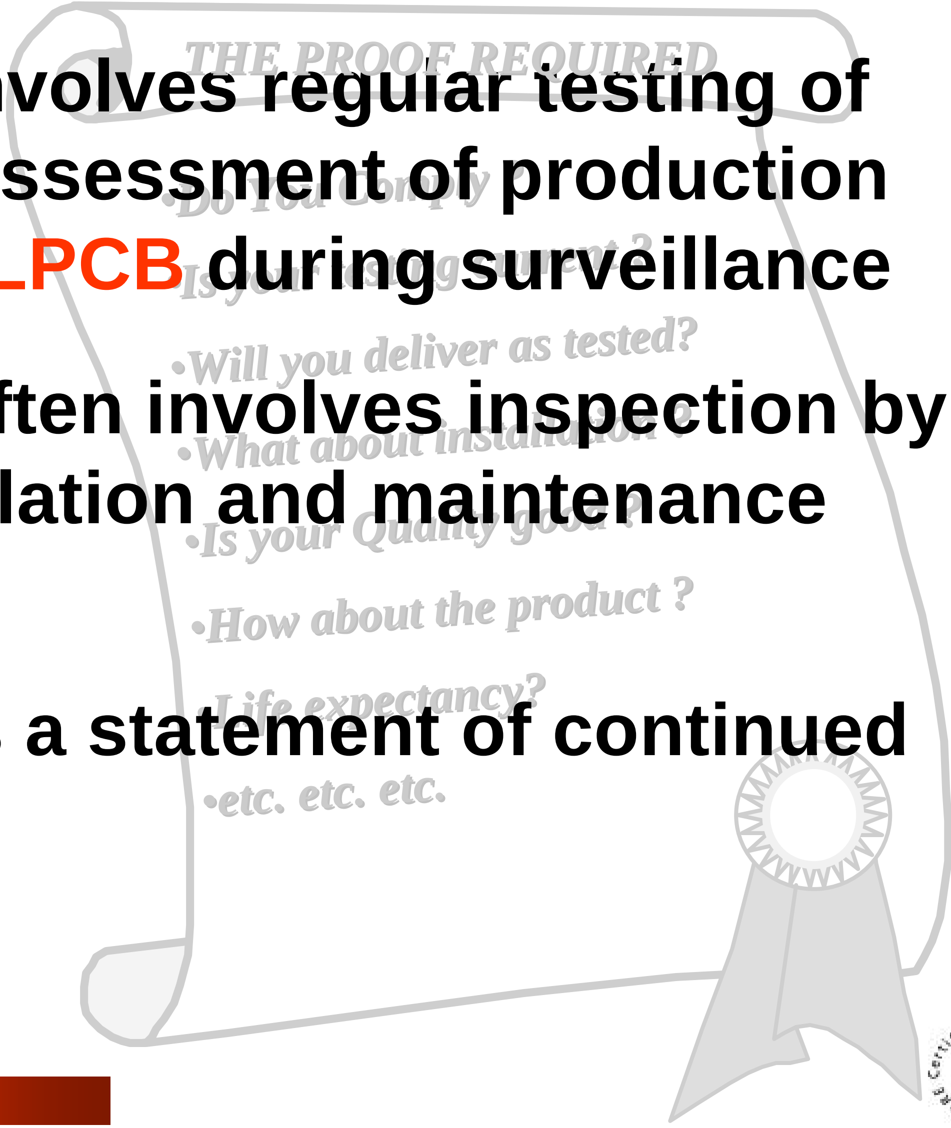
Certification provides:-

- <u>Independent</u> third party confirmation that a product complies with a specific standard
- Test results are evaluated by the certification body - <u>not the manufacturer</u>

contd..

Conclusion

- Certification involves regular testing of samples and assessment of production processes by LPCB during surveillance
- Certification often involves inspection by LPCB of installation and maintenance procedures
- Certification is a statement of continued conformity



Conclusion

'Red Book'

- Used extensively as a specification and reference document
- Also available on-line
- www.redbooklive.com

Successful candidates are listed in the Red Book

EMERGENCY WORKS ON HISTORIC BUILDINGS AFTER AN EARTHQUAKE

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National Fire Brigade - Italy
Comando provinciale VVF Prato

ABSTRACT

The activity of the National Fire Brigade in the field of safeguard and protection of our national heritage was launched on the occasion of the earthquake in 1997. The paper describes the main goals and issues of the operations, which interested a wide territory, rich of cultural building where operational techniques and equipment usually employed in other situations were experimented and used. This intervention has been in any case a source of valuable experience and an appropriate occasion to understand the potential capabilities which can be expressed and made available by the Italian National Fire Brigade in this field A significant support was provided by the S.A.F. teams (Special rescue from heights and depths) of the National Fire Brigade.

Keywords

Earthquake heritage safeguard

* * *

The activity of the National Fire Brigade in the field of safeguard and protection of our national heritage was launched and became immediately a large scale activity on the occasion of the earthquake in 1997. The seismic event affected for several months a large part of the municipalities in the province of Perugia, where historic monuments and works of art are spread everywhere, even in the smallest villages.

Along with the coverage of the seismic event all information media highlighted the salvage interventions of works of arts and safety measures adopted by fire-fighters to protect monuments and historic buildings.

The operations in Assisi attracted a dramatic international interest throughout the world, because they concerned Saint Francis' Basilica, where an unusually powerful seismic wave -which occurred unexpectedly many hours after the first ones- caused the collapse of some parts of the ceiling with frescoes dating back to the XIV century and the death of 2 of the officials of the Monuments and Fine Arts Office who were carrying out an inspection inside the church.

The operations for both the Cathedral of Assisi and the bell tower of Foligno Town Hall dealt with architectural elements placed at remarkable heights requiring the use of special equipment and innovative planning.

In Foligno there was the risk of collapse of the Town Hall bell tower. The tower weighted more than 10 tons and the two bells 500 and 700 kilograms respectively. The operations were carried out at a 45 metre height with really limited manoeuvring space and no escape possibilities for the operators.

The intervention was necessary not only to safely lock the small dome covering the tower (a symbol and a typical feature of the town), but also to prevent damage to people and to the town hall and other surrounding historical buildings which gave a charming effect to the square.

The development of the situation was constantly followed by the information media and the population, because the repeated seismic waves caused visible damages to the structure and technicians had to develop -faster and faster- new intervention plans.

Strengthening and hooping of damaged pillars, plugging of the arches separating pillars, installation of nets and tarpaulin sheets and their filling with plastic foams and the erection of a containment metal cage around the whole structure. These projects on the point of being implemented were systematically put aside after any new tremor which required a different approach.

Then, another greatly destructive seismic wave occurred, which was witnessed in a live show by an audience of millions of people. The fire-fighters who were working on the tower were not injured thanks to their good fortune: they had just stopped working and moved 10 metres aside, when the new tremor destroyed the structure.

This intervention has been in any case a source of valuable experience and an appropriate occasion to understand the potential capabilities which can be expressed and made available by the Italian National Fire Brigade in this field .

In this case operational techniques and equipment were experimented and used which are usually employed in other situations. Significant assistance was provided by the Weskam camera, similar to the TV cameras used to film sports events while flying. It was installed on a F.B. helicopter and connected with an earth station in a Fire Brigade appliance. In this way it allowed the filming at safe distance of architectural elements difficult to approach and technicians were able to check, in a short time, and in detail, all damages in order to plan rapidly the intervention approach.

A significant support was provided by the S.A.F. teams (Special rescue from heights and depths) of the National Fire Brigade. The members of these teams are fire-fighters who have received a special training for the rescue of people and property in caves, rivers and mountains. They are able to work in safety conditions in extremely difficult scenarios, using mountaineering techniques, special harnesses, descenders and special sails, by hanging from the winch of an helicopter or being anchored to crane booms and mobile platforms.

When this initiative was first launched their number was less than 150 units. The operators worked in a dozen Fire Brigade Provincial Headquarters and they were mostly used in rescue operations carried out from an helicopter. The knowledge of these techniques were later disseminated to the whole Fire Brigade personnel and now S.A.F. members can be employed in other operations, such as for the protection and salvage of historical monuments.

The experience gained in Florence is particularly interesting. In this city there was close co-operation among the S.A.F. members, the Documentation Centre of the Provincial F.B. Headquarters and the architects of the municipality on the occasion of the inspection of Palazzo Vecchio, one of the most famous monuments in Florence. The inspection of that building would have required the installation of very expensive scaffolding which would have covered the entire building for weeks. But because of the work of the S.A.F. team it took only 6 days to check all the stones, stuccoes and friezes of facades, columns, arches of the bell tower capitals, ogival arches, gallery vaults and corbels enabling the search for cracks and stone disjunctions.

The TV transmission was carried out by a micro-camera and a transmitter-receiver device with built-in antenna, placed on the helm and the back of the S.A.F. operator. The images were sent to a station sited down in Piazza della Signoria. The whole operation required 12 descends and 7 hours of video recording.

Besides the most famous operations and the usual relief activity for the earthquake stricken population, fire-fighters of Umbria and those coming from other Italian regions carried out in one year more than 500 special operations aimed at recovering works of art, as wells as protecting historical monuments: churches, watch towers, city walls and private buildings (under the protection of the Monuments and Fire Arts Service).

In details these were: 90 roof repairs, 160 proppings of walls, vaults and arches; 90 *hoopins* of pillars, bell towers and towers; 50 removals of unsafe elements and including a large number of inspections and stability checks, propping and cordoning activities.

Fire-fighters carried out also 115 operations to recover paintings, statues and other works of art, bells, church ornaments and vestments, books and documentation. They supported the experts of the Monuments and Fine Arts Service to disassemble 17 organs and altars and to protect ancient frescoes.

These specific operations were initially co-ordinated by the Operational Rescue Centre. Later on the Office of the Delegate Commissioner for the Artistic and Cultural Heritage of Umbria was established: an organic, functional and independent structure devoted to the safeguard of earthquake affected heritage. Here all the intervention requests were gathered and examined which were submitted by experts of the Fine Arts Service or Fire Brigade technicians, trade unions, local or religious authorities and individuals. The Commissioner's Office defined priorities and decided the operations to be carried out.

The activity of the Fire Brigade in this sector was organised by a special office which sent out the F.B. teams composed of masons, carpenters and S.A.F. members, all coming from F.B. provincial headquarters at Umbria and other regions. They were accommodated in a "camp" close to the outskirts of Foligno and an highway junction, where also the heli squad and a warehouse were located for the storage of all necessary materials and equipment.

Thanks to the use of helicopters it was possible to carry personnel and equipment in inaccessible places as well as to recover some bells belonging to monuments, which could not be reached by fire engines. The organisation has gained, besides the experience with new techniques, professional and economic benefits. In fact, as to the budget, the whole mission has saved considerable money because operation costs involved can be considered negligible in comparison with the benefits obtained. Actually, the expenses concerned only the materials employed: wooden boards and props, metal scaffoldings, joints, sails, carpentry materials, lifting belts, synthetic fibre cases, tarpaulin sheets, etc.

There were no planning expenses: the development of projects and working plans had been carried out by Fire Brigade personnel (engineers, architects, land surveyors and industrial experts) during evening meetings or directly on site, thanks to the gained experience.

The final global assessment of the mission shows the value of the savings, because the sites concerned numbered 500, but the operations carried out were more than 500, because fire-fighters had often to come back to the same site in different moments: to demolish shaky elements, to prop other structures, to recover works of art, etc. Even when not considering the costs, we note that a private company would have had problems at closing the operations as rapidly as the National Fire Brigade, because it would have required more time to develop the project, to open the building site and implement all safety measures usually necessary for starting work in safety conditions. Sometimes it would have been impossible for a private company even to reach the affected area, because of blocked roads, proximity of shaky buildings, lack of minimum safety conditions, etc.

Furthermore, the rapidity of intervention was crucial in the quake affected areas for manifold reasons: the operations concerning vertical structures (like bell towers, walls) were all urgent in order to remove the risk of falling stones on other architectural elements (roofs, vaults) containing also frescoes, stuccoes or valuable friezes. Often operations were required to open roads to the traffic.

As to the quality of the operational techniques, many months after the end of the operations all proppings, hoopings and protection works implemented have proved to be absolutely appropriate to absorb the shocks and tensions caused by the never ending seismic waves which have characterised this earthquake in Umbria and Marche. Such a successful result is due to the extreme elasticity of timber and material used, featuring the highest endurance although light and easy to carry.

AN INTERNATIONAL OVERVIEW OF FIRE PROTECTION OF CULTURAL HERITAGE

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SUMMARY

During the last decades, among various countries authorities, fire experts, conservationists and citizens a great concern on the conservation of cultural heritage including fire protection has been arisen.

In this paper a global international review about the state of the art of this important matter is given. It is defined briefly the main terms and the philosophy of conservation, the principles of the fire safety design both in the prescriptive and in the modern fire safety engineering approach.

Information about significant fires in historic buildings and sites, as well on several related international activities of different organizations and bodies is quoted.

Finally a summary of two research activities going on in Europe is described.

1. HISTORIC BUILDINGS AND SITES

1.1 General

During the recent decades and especially since the seventies a great concern about the Conservation and Preservation of Cultural Heritage has appeared in many countries. This universal concern has different reasons, among them the fact that many historic monuments are being rapidly destroyed due an anarchic speculating urban development, which places the man in the margin of social life giving priorities to the “market laws”. On the other hand, with the postmodern movement of environmental protection, the concern on monuments preservation passed from a group of experts to a wide circle of the public. [1]

The protection of monuments is scooping to the preservation of historic and cultural heritage and to the transmission from one generation to the next, in order to keep the cultural identity and continuity of the nations and the people through the centuries. The historic memory of a nation is often based on its technical, political and cultural achievements and creations of the past.

The willing for perpetuity comes from the consciousness of the unavoidable fact of death and the unreturnable current of the time. Man pursues after death glory and fame thinking that it is a way to beat the disappearance and to assure immortality.

The replacement of the buildings with new ones is considered as a natural and reasonable historic evolution by the time running. However, many times this replacement took place unbalanced and in no-normal conditions, so that the regular succession between the past and the future has been disordered.

An event symbolized by the erection of a monument does not always assure its maintenance through the time.It often depends on the consideration given by the future societies in which degree they can evaluate cultural values and on the other hand, how far the creations and the values can resist time. Every society and every season have various criteria for the value and the necessity of monuments conservation. There are cases in the past, when nations destroyed the monuments of other conquered countries in order to exterminate the symbols and to eliminate their national conscience and cultural identity.

The justification for preservation is made economically easier and logically reliable if the restored building is capable of beneficial and profitable use. Present day use brings often the necessity of satisfying present –day standards and codes both for the occupants of and the visitors to the historic buildings.

1.2 Definitions

Speaking about conservation of historic buildings and sites we must use a common language, which has been established by the conservationists during many years and is written in several international texts (Conventions, Agreements etc.)

In the Charter of Venice (1964) the definition of the historic monument does not cover only the architectural creature, but many times an urban or rural area as an evidence of a historic event or a specific civilization. It does not refer only in aesthetically famous creations, but also in modest anonymous works which gained through the time an important cultural value. [2]

Conservation is defined as the technical intervention to protect a historic monument or a traditional or listed building from dilapidation and to restore it.

The main characteristics of a monument are considered the following:

Originality or *innovation* which refers to the special value of every monument, that could not be repeated even in the case of a precise copy, since it includes a correlation of those components and parameters consisting an original creation.

Time (historicity), which includes all time phases and interventions to the monument, giving the chronological sequence of events in the life of the creature.

Quality, which is difficult to be defined since the elected evaluation system is several times subjective depending on the ideology and the aesthetic criteria of every society and each period.

That was the reason why a fourth criterion that of *symbolism* was added, in order to declare the message from the past contained in the monument and is expressed with each accurate form.

In the meeting of 21 member-states of European Council in Granada of Spain (1985) dilated meanings of *monument, architectural complex* and *historic site* were established. It was agreed that these terms include not only archaeological and artistic masterpieces or significant historical heirlooms, but also buildings, complexes or areas with a special scientific, social or technological interest.

2. CATEGORIZATION OF HISTORIC BUILDINGS

From the point of view of fire safety the categorization of historic buildings in a fire system evaluation is needed. Categories of historic construction and fire safety evaluation must be used to assess the inherent fire risk and the need of architectural and cultural sensitivity in order to apply either modern fire codes or any available alternative approaches.

A proposal [3] for historic buildings categorization is based on:

Occupancy, which means the use or the intended use of a structure, in terms of estimated number of people present and whether or not modern or historic functional processes are being performed.

Building type refers to the nature of historic construction as the size of the building, the nature of the fabric.

Risk, which more or less is inherent in all structures and especially in historic any loss is considered harmful.In the process of fire risk analysis four major steps could be intentified [4]:

Hazard identification

Risk estimation

Risk evaluation and

Risk reduction

Cultural contents. Building Codes classify and regulate the hazard of contents either they belong to modern or to historic contents.

Cultural values may be archaeological, architectural, historical, artistic, symbolic etc.

Although historic buildings represent a very small proportion in the total number of buildings, they consist of a wide range including castles, palaces, churches, ancient and some prehistoric monuments, as well as museums, libraries, traditional buildings and historic city and other settlements etc. On the other hand, there are significant historic contents inside either historic or modern buildings like icons, frescos, manuscripts, paintings, statues etc.Some of these cases are shown in the following pictures.

Fig. 1 The keep of Himeji Castle (Japan)

Fig. 2 The piazza of St Peter's

Fig. 3 Mt Athos monastery (Greece)

Fig. 4 Manuscript miniature (Mt Athos)

3. FIRE SAFETY IN HISTORIC BUILDINGS

3.1 Monumental fires

Fire was one of the most serious threats for the buildings and sites through the centuries.This threat is omnipresent and results irreplacable losses.Most of the historic built-environment has been destroyed from various reasons, as mentioned above, and it is time to preserve any of the humanity cultural heritage remained to remind us the past and the history.

Although most of historic buildings have built in periods when very poor, if not at all, Fire Codes and Standards were applied, many of them exist now in their original condition after such a long time.That happened because, on one hand the traditional builders and architects applied several sophisticated fire protection measures based on the state of the art at that time as well on common sense and on the other hand, after major fires and conflagrations the authorities put in force more severe and more developed fire protection legislation.

We shall refer below to some of the so called “monumental fires” in historic structures, which had an international fame:

The fire of the wooden wall and of many temples of the Athenian acropolis by the Persians (480 B.C.-Herodotus, III 52).

After this complete destruction of the first Parthenon, Athenians built the new Periclean Parthenon which, although heavily damaged through the centuries, survive up to now.Two large fires destroyed most of the valuable parts of the monument. The first one was put by the strange Celtic tribe of Eruls pyromaniacs on the year 267 A.D. The second fire was due to the Venetian F. Morozini (1687 A.D.), who bombed the temple of Parthenon completing the destruction of the Celts [5].

Rome (Galatians 387 B.C.)- (Nero 64 A.D.)

Library of Alexandria (Julius Cesar 47 B.C.-Aurelianus 270 A.D.-Serapeion 391 A.D. and Kalif Omar 641 A.D.)

CHURCHES DESTROYED BY FIRE DURING RECENT YEARS:	DATE OF FIRE
Hôryû-ji temple, Nara Japan (7th A.D century)	1949
Kevelar (15th century) Germany	
York Minster (15th century) UK	July 1984
Luxemburg (15th century)	
Klein-Krotzenburg (15th century) Germany	
Bielefeld (19th century) Germany	
Münster of Freiburg (13th century)Germany	
Dom of Berlin (18th century) Germany	
Monastery of Simomopetra (14th century), Greece	August 1990
Christianborg Palace Church, Copenhagen, Denmark	June 1992
St George's Church, Halifax, Canada	June 1994

Fig. 5 Fire in Simonopetra

CASTLES/PALACES:

Philippsruhe,Hanau, Germany	
Hampton Court Palace, England	March 1986
Purschenstein, Neuhausen, Switzerland	
Redoutensal, Hofburg Palace, Vienna, Austria	November 1992
Windsor Castle, England	November 1992
Pont de la Chapelle, Lucerne, Switzerland	August 1993

CITIES:

London Great Fire (1666) was the initiator of building regulations in England. The easterly wind assisted the fire spread and highlighted the need of buildings separation and the control of their walls and roofs ignitability.

Jamestown, Virginia USA (1608)

Plymouth, Mass. USA (1623)

Manhattan New York, USA (1628)
Edinburgh Great Fire (1824)
Chicago, USA (1871)
Aalesund, Norway (1904)
Risor, Norway (1716, 1861)
Thessaloniki, Greece (1917)
Lisbon-Chiado, Portugal (1988)
South Bridge/Cowgate-Edinburgh (2002)

Fig. 6 Thessaloniki fire (1917)

3.2 Objectives

Although fire safety objectives have been expressed in different ways by different authorities in different countries, generally there are accepted two main aspects of fire protection for modern buildings: *life safety and property protection.* For historic buildings it must be added the *protection of cultural values* either for the buildings or for their contents. It is not possible to achieve an absolute fire safety. In most cases, a proper fire safety design assume that a limited unwanted fires will occur and means shall be provived to minimize the losses from fire till an acceptable level.

3.3 Measures

The main safety measures in connection with the above mentioned objectives are the following:

Reducing the causes of fire incidence

Providing means of escape for the occupants and the visitors of the buildings

Preventing rapid growth of fire

Preventing internal fire spread

Preventing external fire spread

Controlling and extinguishing of fire

The Building Regulations and Codes prescribe the minimum fire safety requirements. Generally the national or the municipal fire legislation concerns for life safety, whereas insurance-orientated Codes are designed to minimize loss property.

3.4 Advanced fire safety design

In planning for fire protection of historic buildings the following main steps should be proceeded by the designers:

Make a risk assessment

Develop fire safety criteria

Identify fire hazards

Consider building's arrangement

Plan a fire protection strategy

Specify passive fire protection

Specify active fire protection

Develop a fire safety management plan

It may be feasible to use traditional approaches for some historic buildings, where they can be categorized in one of modern occupancies (i.e.offices,museums etc.). However, for the majority of historic buildings, especially those erected many years ago, such an approach could cause not only serious technical and finacial problems, but it might lead toundesired results about the historical and architectural character of buildings, which is often unacceptable by the conservationists.

It would be necessary either to go through a clear and sophisticated process like that mentioned above, or to use a modern fire safety engineering methodology, which principles are described in the ISO Technical Report 13387 (1999)

INTERNATIONAL ACTIVITIES

Review

The year 1975 was declared as the "year of protection of cultural heritage" by the European Council. Lord Duncan spoke about the demand of fire protection of the remained cultural heritage as European community first priority.

On behalf of German insurers group Kallenbach et. Al published a documentation of important losses of German historic buildings in peace-period since 1945.

Kabat presented his experiences with fire safety concepts for historic buildings in the famous cathedral of the city of Worms in Germany

The German Fire Protection Association (VFDB) used their annual meeting (1987) to bring the attention of the public to the problems of fire protection in historic buildings. [6]

The international Symposium "Protection of cultural heritage against the threat of fire" hosted in Karlsruhe (1990) co-organized by VFDB (prof. W. Becker) and CIB- WG 014 (Dr. P. Thomas-prof. K. Papaioannou). As consequence of that Symposium new guidelines of CIB had been drafted by K. Papaioannou (Aristotle University-Hellas) and H.L. Malhotra (Fire Research Station, UK) et. al.

"Conservation of Cultural Heritage" is a stated goal of the ISO-TC92-SC4 (Fire Safety Engineering) ISO/DTR 13387-1 (1998)

The CIB W014 Working Commission has recently identified seven projects as those of high priority, including a "guidance document on rational fire safety engineering approach to fire safety in historic buildings". This represents ongoing work that was initiated on July 1987 in Thessaloniki where a sub group concerning fire in historic buildings was formed.

Among other European activities are included the following:

- 1st Polish Symposium “Chosen problems of Fire Safety in Historical Objects”-Cracow, Poland 22-23 Sept. 1986.
- “Fire Protection of Historical Buildings and Urban complexes” Thessaloniki, Greece 1987 “Fire Protection of Historic Buildings and Towns”-Risor, Norway September 1990
- “Fire safety and Conservation of Cultural Heritage”-VFDB Karlsruhe Germany 1990
- “Fire Protection of Historic Buildings and Sites”-CIB W14-Kalithea Greece 1994
- “Fire Protection of Ancien Monuments”-Cracow Poland October 1994
- “Fire in Historic Buildings”-CIB-ISO-Santorini Greece 1996
- “Fire Protection and the Built Heritage”-Edinburgh Scotland 1998
- Duff House, Scotland 1998
- Versailles, France 1998
- Schonbrunn, Austria 1999
- “Fire Protection of Historical Monuments” Chestochowa-Cracow Poland 1999
- Rome, Italy 1999
- “Fire Protection of Cultural Heritage” AUTH-CIB, Thessaloniki, Hellas 2000
- Stockholm, Sweden 2001
- Schonbrunn, Austria 2001
- Kyoto, Japan CIB-ISO April 2003
- Rome, Italy April 2003

UK National Events included:

Fire and Historic Buildings, Anwick Castle	1994
Heritage Fires (FPA), London	1996
Books do Burn, Edinburgh	1996
Protecting our Heritage, Liverpool	1997

Heritage Fire Safety (FPA), Belfast	1997
FineFire Conference, Cambridge	2001

4.2 Research projects

A summary of two important European research activites is given below.

4.2.1 **A European Concerted Research Action designated as COST**

Technical Annex

Summary

The intention of the Action is to address the physical and significant cultural loss of Europe's built heritage to the damaging effects of fire. It will be achieved in a multi-disciplinary, multi-national manner through the collaboration and integration of a variety of related projects. It will also build upon current research initiatives and recently published material resulting from a number of relevant international conferences. The outcomes will be the promotion of data, methodologies, and management systems. This will assist a wide range of end-users balance fire engineering needs with conservation requirements in the future preservation of the European patrimony.

1. Why a COST Action on this topic

In addition to associated levels of life loss, the number, authenticity and quality of European historic buildings is being steadily eroded through the effects of fire. In 1983 this was recognised by the Council of Europe Committee of Ministers, who recommended '*That the governments of the member states adopt all legislative, administrative, financial, educational* *and other appropriate measures'* to protect the built heritage from fire and other natural disasters. Therefore there is a need to find a balance between technological and management solutions to counter this disastrous effect of fire.

The real scale of loss of historic buildings to fire is unknown but superficial data suggests that the annual and aggregated effect is considerable, perhaps as high as one important historic building each day.

There is a general lack of statistical information, and a common lack of understanding and appreciation of what measures are available and required, to counter the effects of fire. Good guidance is urgently called for on how to sensitively retrofit modern day equipment into historic fabric. There is also a need to develop related management expertise in the dealing with this problem in historic premises.

2. Status of the research in the field

To assess the specific risks to a historic building requires the need to define possible, or expected, damage due to a particular hazard or phenomenon. The term "historic building" should be taken to be synonymous with the entire architectural heritage - comprising monuments, groups of buildings and sites, as well as movable objects having particular historical or aesthetic association with the protected building. There are a considerable number of historic buildings requiring protection. It is important to recognise that these historic buildings are a major contributor to the 'sense of place' and recent information indicates that they are of great importance to both inhabitants and tourists. In some

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[1] *Recommendation No R(93)9 of the Committee of Ministers to Member States on the Protection of the Architectural Heritage against Natural Disasters*

[2] *Cf. Council of Europe – Committee for Cultural Heritage 1992.*

[3] A MORI poll undertaken for English Heritage indicated that of a representative sample of 3000 people in England, 76% think that their lives are richer for having the opportunity to visit or see the historic environment and 88% think that it is important in creating jobs and boosting the economy *English Heritage, 2000, Power of Place: The future of the historic environment*

countries, the most important historic buildings are included on statutory lists. However, the criteria for selecting buildings for inclusion change from country to country. These listed buildings form only a small percentage of the total number of buildings which can be considered as part of the built heritage. As an indication, there are almost 36,000 listed buildings in Austria, 110,000 in Bavaria and 45,000 in Scotland, but detailed figures for all of Europe are lacking.

To be effective in the resolution of this problem, the need is to develop a high level of international co-ordination and strengthen the levels of trans-national multi-disciplinary co-operation. The need is to exchange and enhance experiences to increase awareness and understanding, and to focus future action. Networking partnerships have been identified, their specialist input recognized and roles they perform classified. The associated skill and knowledge needs to be pooled, assessed and best practice developed.

During the 1990's several international conferences considered the topic of fire loss to the built heritage. But these did not provide the mechanism for encouraging and co-ordinating research projects. However, published proceedings offered an established understanding of the issues, although many of them remain un-resolved in practical terms.

3 Objectives of the Action and Scientific Content

Across Europe the full extent of the physical loss of the built heritage to the effects of fire is unknown. Some suspect it to be as high as one important historic building each day, but there are no reliable statistics upon which the real degree of destruction and cultural loss can easily be established.

In integrating new technologies with traditional disciplines there is a need to develop synergies within related organizations so that loss levels can be reduced and, ideally, halted. The underlying objective must be to retain the

[4] A potential mechanism for co-ordinating research, and a means to disseminate information on research carried out, exists in the *English Heritage Fire Research Database* which was established early in 2001 (http://194.6.81.149/eh_fred/fredinfo/fredframespage.htm)

remaining cultural built heritage in an authentic state for future availability, access and enjoyment by all. This requires making best use of the limited resources available and recognizing that conservation is a cultural process – however the priorities may not be the same in all partner countries.
There is, therefore, an urgent need to integrate, co-ordinate, and assess the associated factors on a pan-European level so that a common state of the art understanding emerges to help combat such levels of loss.
To address the problem a pan-European integrated approach is required.
The operational framework will consider the:
Vulnerability of historic buildings to fire

Risk assessment methodologies

Protection of fabric and content

Prevention of fire and fire spread

Detection and suppression requirements

Training and management of staff

Insurance considerations.

This will call for the development of:
The compilation of appropriate statistical information, including an analysis of expert opinion on the rate of loss of historic buildings to fire.

A common state-of-the-art understanding, and appreciation, of available appropriate countermeasures; this should include concerted action to influence future developments in technology.

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[5] *"All judgements about values attributed to cultural properties as well as the credibility of related information sources may differ from culture to culture, and even within the same culture. It is thus not possible to base judgements of values and authenticity within fixed criteria. On the contrary, the respect due to all cultures requires that heritage properties must considered and judged within the cultural contexts to which they belong."*
Quote from the Nara Document on Authenticity, 1994, Agency for Cultural Affairs (Government of Japan) and the Nara Prefecture in co-operation with UNESCO, ICCROM and ICOMOS.

[6] Using data from various published Conference Proceedings

A relevant understanding in the financial protection of historic properties

Guidance on the sensitive integration and retrofitting of countermeasures.

To achieve meaningful results during the life of the Action, a strategic approach needs to be adopted. Through addressing implicit terms and problems to help achieve relevant solutions, work will focus on-
Compiling statistical data on the extent of Heritage at risk

Promoting statistical research into the consequences and causes of fires – both major fires and more minor incidences, (e.g. small fires to which the fire brigade are not called or false alarms) – and their impact. Using this risk mapping data gathered as a basis for discussion, establish a dialogue with insurance bodies to seek the development of insurance products more closely tailored to historic buildings.

Establishing a well-documented survey of state of the art technical expertise to assist in influencing future developments in fire protection technology for use in historic buildings.

Defining an appropriate range of passive and active technical equipment countermeasures.

Considering alternative approaches to assist in stemming current loss levels

Organising a series of conferences and/or workshops to develop thinking for effective Risk Assessment techniques and risk mapping using insurance company and other data.

Promoting findings and benefits of relevant risk assessment methodologies and property management support.

Effecting know-how dissemination through publishing proceedings and recommendations.

[7] These are fires that it will be very hard to find data on. Individual property owners and managers may have to be approached for this information.

In particular the results of the COST Action should be targeted to building owners, property managers and conservation professionals to increase awareness and understanding.

4.2.2 ***Fire Risk Evaluation To European Cultural Heritage***

Quantification of priorities and optimisation of fire protection strategies

<u>Problems to be solved:</u> Fire is a very important threat to cultural heritage. Protection of cultural heritage has had, up till now no high priority in the fire safety business. The resources available for protection of cultural heritage against destruction by fire are limited and often insufficient for the perceived needs. Authorities – European, national and local – have to select the projects on an intuitive basis, as there is no guidance available. A first problem is caused by the fundamental difference between the fire protection of conventional new buildings and cultural heritage. In conventional buildings the main goal of the regulators is the protection of human life, while in cultural heritage the protection of the heritage is at least as important as the protection of human life. Furthermore, authorities in charge of the protection of cultural heritage, find no support in prescriptive national fire safety regulations, there is a lack of well-found methods allowing a correct evaluation of the fire risk incurred by cultural heritage and they miss the tools to estimate the efficiency of different fire protection measures.

<u>Scientific objectives and approach:</u> The first scientific objective is the development of an evaluation tool taking into account all the parameters expected to influence decisions when prioritising fire protection projects in cultural heritage. This objective includes the elaboration of quantitative methods or the adaptation of existing ones for the evaluation of the different parameters/criteria intervening in the decision process. These parameters are the fire-risk, the efficiency of the measures, their cost.
In parallel with scientific objective one, the second objective is to give an overview and examine the relative benefits and drawbacks of the various components of fire safety techniques. This means a comparison between

the different possible strategies of protection, identification of the weaknesses of the existing techniques and the proposal of alternative solutions. Usual fire protection techniques are often not applicable and/or not acceptable for the protection of cultural heritage. There is important lack of specific information on fire safety technology for cultural heritage.

Expected impacts: Under this project an evaluation tool will be developed to assist authorities in prioritising fire protection projects and selecting projects on the basis of objective criteria. These will take into account all the selected criteria/aspects in order to optimise the use of the available financial resources by the selection of those projects providing the highest gain for the investment made.. Additionally a guide will be developed describing the state of the art of fire safety technologies and the use of fire safety engineering approaches to protect cultural heritage. The information will be made available to all interested parties by means of a symposium organised at the end of the project and the publication of a guidance document under book format.

Scientific/Technical objectives and innovation

Fire is a very important threat to cultural heritage. Protection of cultural heritage has had, up till now no, high priority in the fire safety community. Those involved in the safeguarding of cultural heritage against fire damage often lack important information. Under this project therefore an evaluation tool will be developed to assist authorities in prioritising fire protection projects.

Additionally a guide will be developed describing the state of the art of fire safety technologies and the use of fire safety engineering approaches to protect cultural heritage.

This proposal consists of two main objectives:

* Objective 1 is the development of an evaluation tool, which can assist the authorities in defining priorities and selecting projects on the basis of objective criteria. A quantitative method will be developed which can take into account all the selected criteria/aspects in order to optimise the use of

the available financial resources by selecting those projects providing the highest gain. It is the highest reduction in fire losses for the investment made that will be defined, by using improved and adapted potential damage assessment methods. This quantitative method has to assist the authorities when deciding on priorities of the fire protection projects in cultural heritage.

The scientific objective is to develop an evaluation tool taking into account all the parameters expected to influence decisions when prioritising fire protection projects in cultural heritage.

This objective includes the elaboration of quantitative methods or adaptation of existing ones for the evaluation of the different parameters /criteria intervening in the decision process.

These parameters are:

- the efficiency of the measures;
- their cost

An optimisation method will be selected, adapted or developed to integrate the effect of the parameters in one complete evaluation tool. The relative influence of the individual parameters and the evaluation tool will finally be checked in a sensitivity study and a series of case studies.

* Objective 2: In parallel with objective one, the second objective will give an overview and examine the relative benefits and drawbacks of the various components of fire safety techniques. This means:

an examination of the relevance and value of the components of fire safety systems in cultural heritage environments;

a comparison of the advantages and disadvantages of the different possible strategies of protection, i.e. active protection, passive protection, fire protection management, etc;

an identification of the weakness of the existing technologies and examination of the need for adaptation of the protection systems

the need for new technologies for fire protection to cultural heritage;

an overview of fire safety management methods and their efficiency on risk and damage reduction;

an overview of the behaviour of ancient materials under fire conditions

The collection and analysis of real fires which occurred in cultural heritage will constitute background information in support of the two main objectives in this study.

Innovation

State of the art

Cultural heritage has been poorly served by the fire safety community. Little research effort has been spent in this field. Preservationists have to rely on the fire protection technologies used for other, conventional buildings, whilst at the same time they often have to satisfy prescriptive regulatory obligations which are difficult or impossible to satisfy for heritage buildings.

Within the C.I.B. (Comité International du Bâtiment) W14: ‘Fire safety’ a small task group has a declared interest in fire protection of cultural heritage. This group has organised a seminar on the subject ‘Fire Protection of Cultural Heritage’ in Thessaloniki (Greece) on 1-2 June 2000.

The standardisation comité ISO TC 92 ‘Fire safety’ through its SC4: ‘Fire safety engineering’, has fire safety of cultural heritage as one of its potential future fields of interest, but has till today no activities in this field.

Annually large fires destroy important amounts of cultural heritage, but no systematic data collection or analysis of the fires is carried out with the aim to learn from the losses.

Most European countries continue to apply their protective regulations on cultural heritage, the consequence of which is a poor protection, as many of the existing technologies are neither applicable nor efficient under such circumstances.

There is an important knowledge gap between the fire safety community and the preservationists. The application of fire safety engineering methods therefore remains the privilege of a small group of professionals.

Innovative aspects of the project

The problems of fire protection of a cultural heritage will be approached from the viewpoint of 'fire safety engineering'.

Important recent fire losses of cultural heritage will be systematically listed and analysed. Conclusions will be drawn on the origin of the fires, their development. A fire risk analysis method focussing cultural heritage will be elaborated.

Existing fire protection techniques will be reviewed in respect to their applicability, reliability, efficiency and cost. The fire behaviour of ancient building products will be described. The results will be made available to preservationists in a global publication.

A quantitative optimisation method will be elaborated to assist authorities when selecting projects to spend the financial means in the most efficient way. The optimisation method will combine aspects such as fire risk, efficiency versus cost of protective techniques.

Fire safety engineering approaches will be analysed and evaluated for their potential merits when applied in cultural heritage.

Project Workplan

Principal contractors = steering group		Members linked to principal contractor	
1	University Ghent (RUG)	8	University of Innsbruck (UIBK)
2	Warrington Fire Research (WFR)		
3	Instituto Superior Técnico (IST)		
4	Netherlands Organisation for Applied Scientific Research (TNO)	9	University of Venice (IUAV)
5	Centre Scientifique et Technique du Bâtiment (CSTB)		
6	Braunschweig University of Technology (TUBS - iBMB)	10	Fire Safety Nordic (FSN)
7	Aristotle University of Thessaloniki (AUTH)	11	Non-profit Company for Quality control and Innovation in Building (ÉMI Kht.)

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THE INTEGRATED SAFETY/SECURITY SYSTEM OF "ACCADEMIA NAZIONALE DEI LINCEI" AT CORSINI PALACE IN ROME

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ABSTRACT

Owed to the historical importance of Corsini Palace that hosts the "Accademia Nazionale dei Lincei" and due to the presence of a high number of ancient and rare books, volumes, and manuscripts, it has been necessary to study, design and install a proper integrated safety/security system capable of protecting the whole library, from fire, damaging, vandalism, thefts, and unwanted intrusions. It this paper an integrated safety/security system which is capable of reducing a great variety of dangers and risks is presented, together with a very advanced installation design technique based on genetic algorithm optimisation that is capable of ensuring high performances of the system and significant reduction of the costs.

Keywords: Integrated safety/security system, genetic installation design optimisation.

1. INTRODUCTION

Thanks to the continuous technology development it is possible to realize new varieties of devices, sensors and other powerful instruments which allow to implement advanced safety/security systems that show all their power when they are properly integrated in higher level systems [1-3].

In this paper we illustrate the capability of the integrated safety/security system designed and installed in the "Accademia Nazionale dei Lincei" at

Corsini Palace in Rome, its advanced functionalities, and the integration modalities with a telecommunication network.

The author has designed and directed the installation phase of this proper integrated system that manages and controls the safety and the security of this historical palace and of the related precious library, using an advanced system that integrates anti-intrusion, video surveillance, fire revealing, ensuring a high safety/security level of the whole structure.

The integrated safety/security system allows to the personnel, located in different places of the palace, to check directly each zone of the library and to be immediately informed if a dangerous event takes place.

The integrated system has been properly divided into safety/security sub-systems so that each sub-system is capable of working even in the case of malfunctioning of the other systems.

The system is capable of performing a plenty of advanced functionalities that prevent dangerous situations.

2. THE “ACCADEMIA DEI LINCEI” AT CORSINI PALACE IN ROME

The palace has changed its original name of Lungara palace after its purchase made by the noble Florentine family of Corsini. In fact some members of the Corsini family decided to move from Florence to Rome after that a member of their family, Lorenzo, was elected Pope in 1730, with the name of Clemente XII [4].

(A) (B)

(C) (D)

(E) (F)

Fig.1 Pictures of Corsini Palace. a) Entrance of Accademia Nazionale dei Lincei (Villa Farnesina side). b) Back yard . c)-d)-e)-f) View of some interiors saloons.

After the purchase, the palace was deeply renewed and enlarged, adding the gardens, the prestigious library, the picture gallery, and some new parts.
The palace was sold to the Italian State in 1883, to host the Accademia Nazionale dei Lincei, together with the library and the picture gallery, that constitutes the first nucleus of the National Ancient Art Gallery. The library was later named Lincei's library. At the moment of the sale the palace was long about 108 meters, that is its actual length, along the Lungara street direction.
The Accademia Nazionale dei Lincei is one of the most prestigious Italian scientific institution. It was founded in 1603 from Federico Cesi, Marquise of Monticelli and Duke of Acquasparta, and it represents the first scientific academia of the modern age. It was originally located in Cesi palace in Rome, to be later moved to Corsin palace after its purchase made by the Italian state.
The library of the Accademia Nazionale dei Lincei is composed by three sections: the Corsinian library, the Academic section and the Oriental section. In the whole library, after the last inventory of 1993, there are about 600.000 books, manuscripts and parchments.
The National Ancient Art Gallery is composed by 370 pictures coming from the Corsini collection, plus other pictures coming from other private collections.

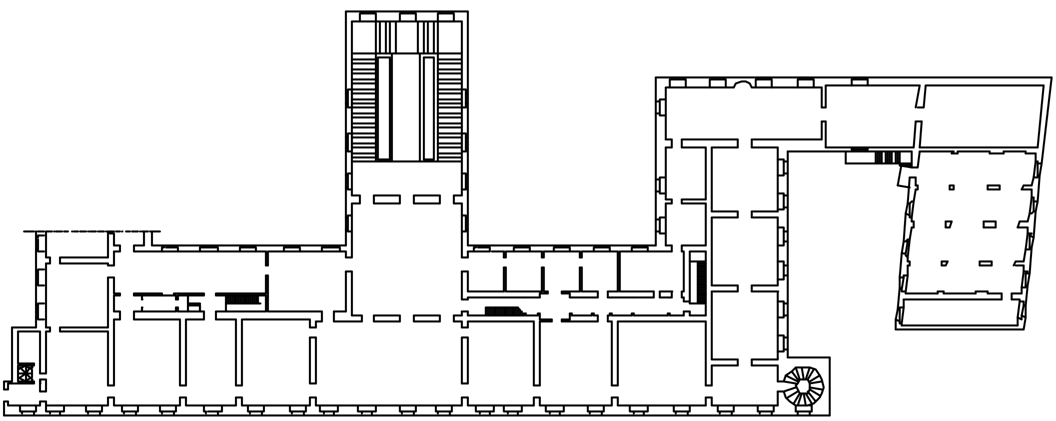

Fig.2 Plant of a part of the Accademia Nazionale dei Lincei library, where the integrated safety/security system has been installed.

3. THE INTEGRATED SAFETY/SECURITY SYSTEM

Owed to the importance of the historical Corsini Palace and of the related precious library, and owed to the presence of a so high number of precious and rare books and manuscripts, it has been necessary to study and design an integrated safety/security system capable of protecting the whole structure from fire and voluntary intrusions, for damaging, vandalism and sabotage, that would compromise a unique historical heritage if they take place.

The designed system allows the capillary control and the total visibility of the protected structure, using advanced architectures and design solutions.

In this paper we illustrate only the general features and philosophy, without getting into details, to avoid of compromising the intrinsic safety/security due to the divulgation of significant informations.

The safety/security system shows anyway interesting features from the potentialities and functionalities point of view.

The integrated system is aimed not only at increasing the total safety/security level of the structure but also at optimising the duties of the control personnel.

The scheme of the integrated system is shown in figure 2.

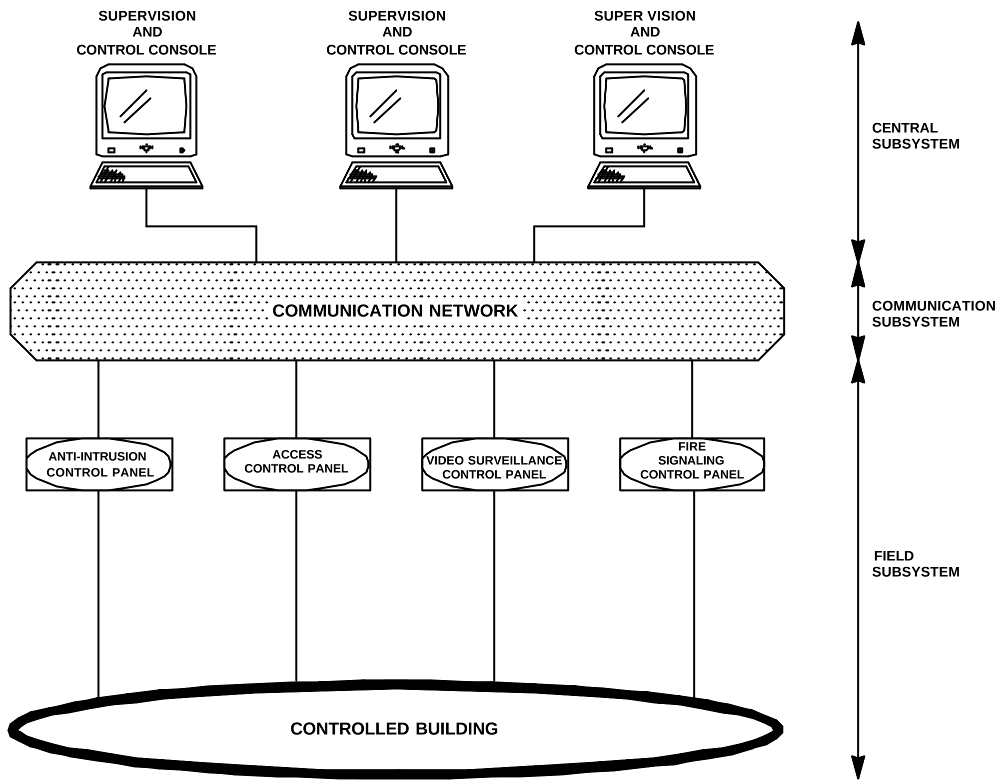

Fig.3 Scheme of the integrated safety/security system

The whole system is divided into specialized subsystems (fire signaling, anti-intrusion, video surveillance, access control) that are totally autonomous from the operative point of view, but that are strongly integrated by the communications and functionality point of view. This choice guarantees a higher reliability of the integrated system.

The system is also composed by three supervision consoles that allow to control each single zone of the palace, according to growing hierarchical access levels, ensuring a high security level to the control of the system.

The security subsystems take care of controlling the intrusion detection and the video surveillance and they are capable of interfacing with the other installations such as fire signaling and so on. These installations are controlled by proper security central boxes that are autonomous from the functionality and power supply point of view and they are able of working even in the absence of functionality of the hierarchical superior system.

The Corsini Palace, and particularly the library, is characterized by a great number of rooms and saloons, that are located at a great distance between them and also on different floors: this situation generates some problems to be solved in terms of the number of signals to be transmitted on a mean distance and in terms of security policies to be managed from the integrated system.

3.1 THE SAFETY/SECURITY INSTALLATIONS

All the control panels related to the safety/security installations (fire signaling, anti-intrusion, video surveillance) use a loop communication bus with hubs. Each control panel communicates with the supervision consoles. The field sensors are connected to the control panel through the hubs and the loop bus while the elements that are located closer to the control panel are directly connected to it by means of a cable.
The block diagrams of the used safety/security installations are shown in figures 4 ,5,6.

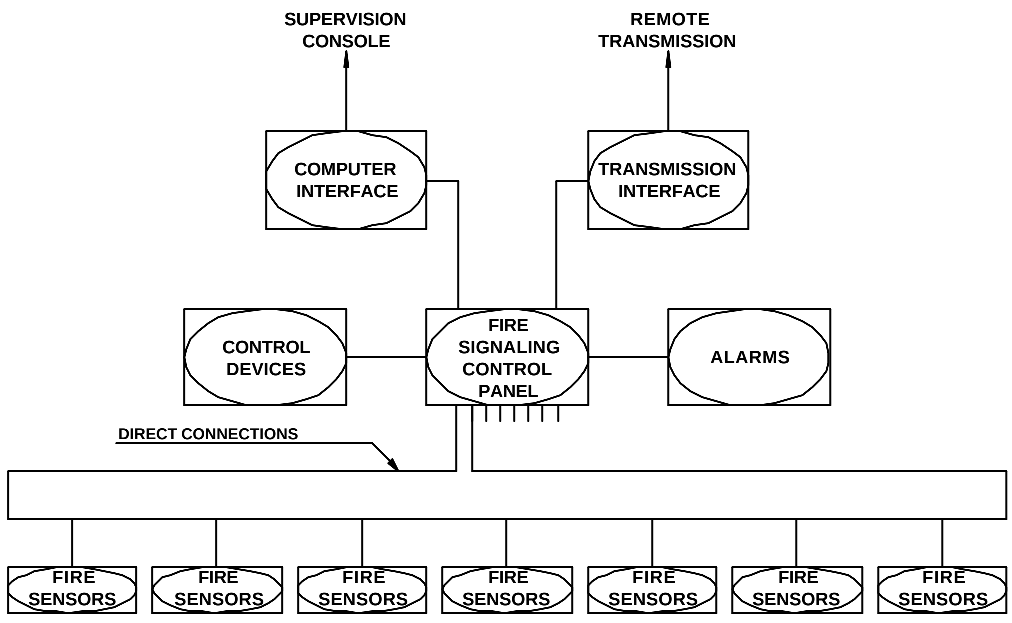

Fig.4 Block diagram of the fire signaling installation

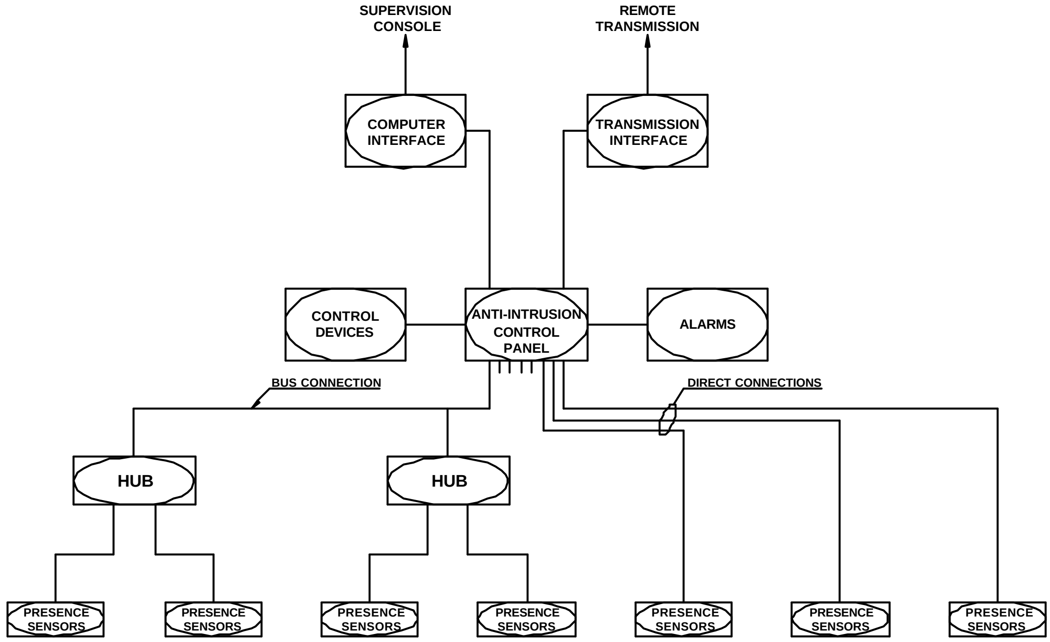

Fig.5 Block diagram of the anti-intrusion installation

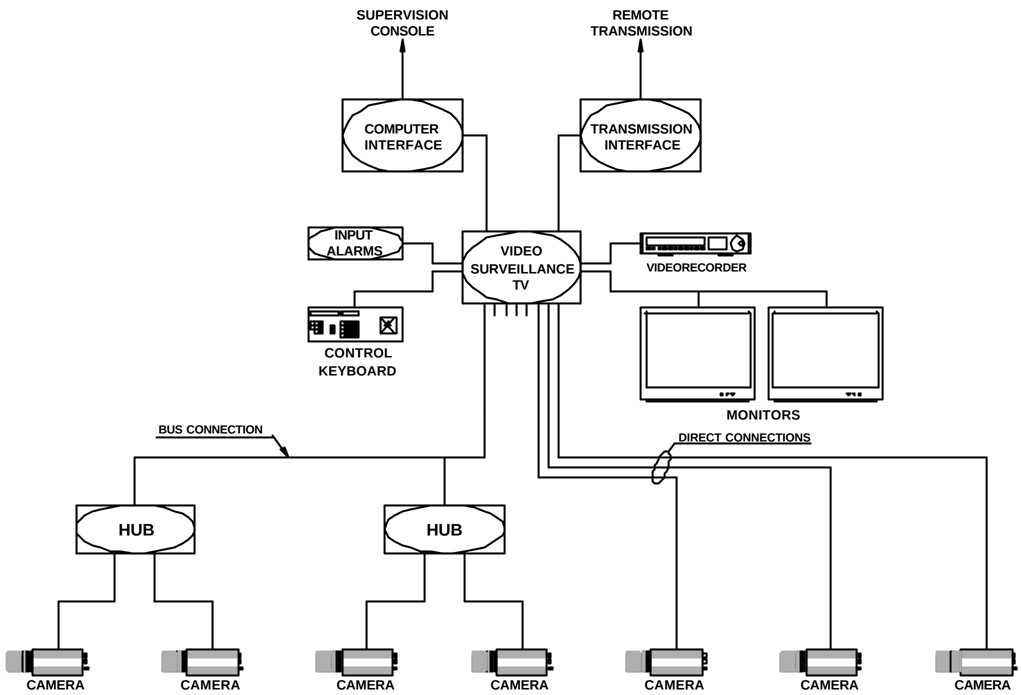

Fig.6 Block diagram of the video surveillance installation

The choice of the loop bus with hubs was made after a proper cost/benefit analysis. In fact the mentioned system ensures to transmit all the informations from the sensors to the control panel and vice versa using only a wire bus.

In this kind of configuration the single sensors are not connected directly with the related control panel, increasing the amount of wire used for the installation with a consequent increase of the cost of the materials and of the human work, and reducing the reliability of the whole installation due to the high number of connections. The sensors are therefore connected directly with the hubs, that are local devices which transmit the safety/security informations received from the sensors to the control panel and vice versa, using a 2 wire bus.

All the installations accomplish the UNI-EN and CEI technical recommendations that concern these kind systems.

3.2 THE COMMUNICATION BUS OF THE INSTALLATIONS

The use of a loop bus increases the reliability level of each single installation since, in the event of voluntary interruption (due, for example, to sabotage) or not voluntary interruption of it, the data exchanged with the hubs towards a given direction can be exchanged using the other direction.

The fire signaling installation uses sensors that are directly connected to the bus while the anti-intrusion installation uses sensors that are connected to the bus using the hubs.

The hubs exchange continuously data with the field sensors, using a proper security protocol, verifying their functionality, and sending proper signaling messages to the control panel in the case of malfunctioning. The used installation architecture ensures high performance of the sensors efficiency.

In the event of alarm the system is capable of activating the safety/security procedures in a short time

3.3 GENETIC OPTIMISATION OF THE SENSORS INTERCONNECTIONS

The number of hubs, their position and the number of sensors connected to each of them represents a typical optimisation problem where it is necessary to reduce as more as possible the installation costs, reducing as more as possible the number of hubs and positioning correctly them so that the amount of wire necessary to connect all the sensors to them is the shorter one.

The input data are represented by:

1) position of the sensors;

2) position of the hubs;

3) sensor/ hub connection cost;

4) hub cost.

The connection conditions are represented by:

1) maximum number of sensors that can be connected to each single hub;

2) maximum distance between two hubs;

3) reduction as more as possible of the number of hubs;

4) maximum length of the bus.

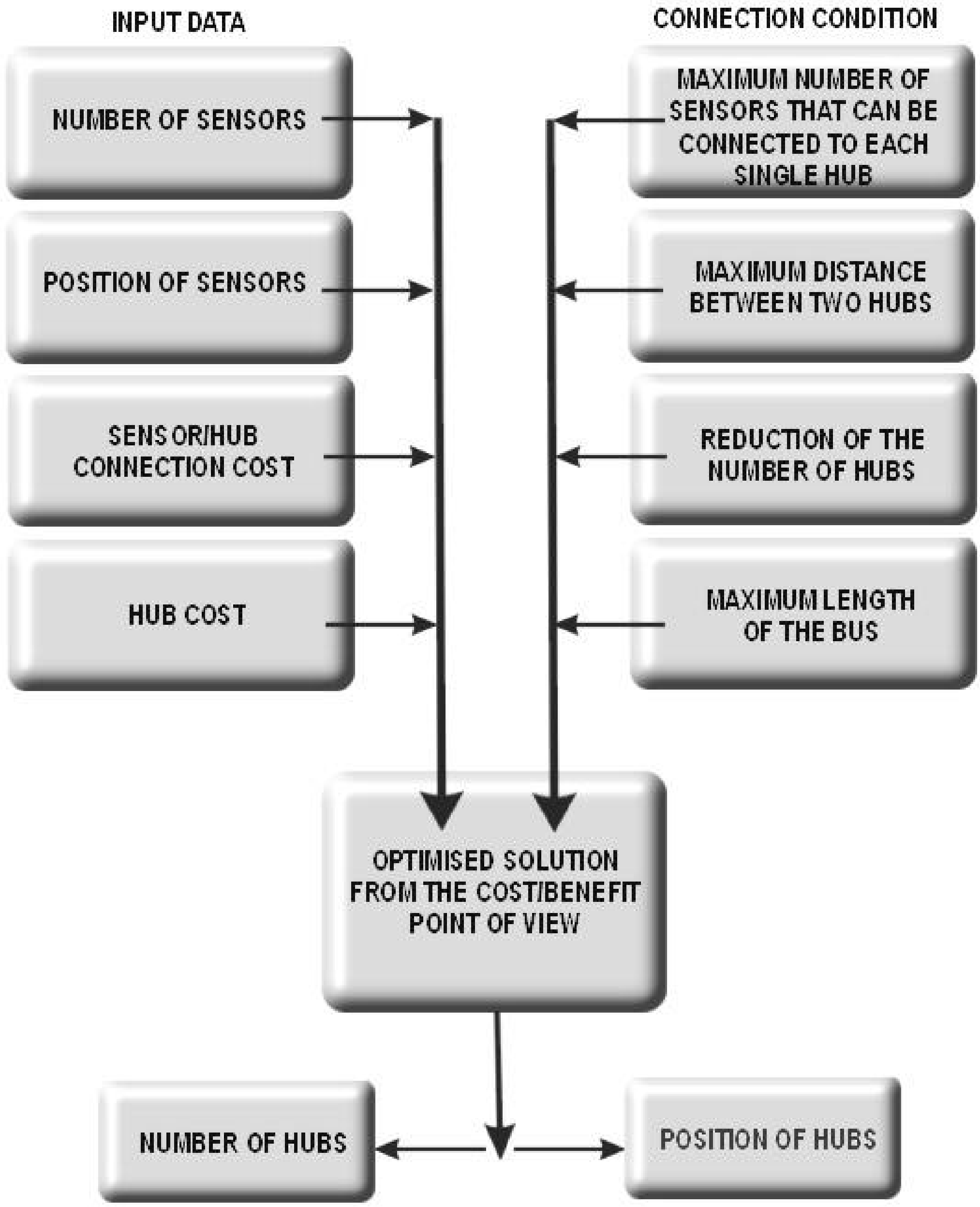

Fig.7 Scheme of the design optimisation problem

This problem can be solved using evolutionary strategies such as the one offered by the genetic algorithms and evolutionary computation [5].

Genetic algorithms (GAs) offer the great advantage of evolving their behaviour to match with the behaviour of the final users, using a mechanism that is very similar to the one used by nature. Different genetic algorithm can be used to achieve the desired purpose, each characterised by peculiar features.

Genetic algorithms are considered wide range numerical optimisation methods, which use the natural processes of evolution and genetic recombination. Thanks to their versatility, they can be used in different application fields.

GAs are particularly useful when the goal is to find an approximate global minimum in a high-dimension, multi-modal function domain, in a near-optimal manner. Unlike the most optimisation methods, they can easily handle discontinuous and non-differentiable functions.

The algorithms encode each parameters of the problem to be optimised into a proper sequence (where the alphabet used is generally binary) called a gene, and combine the different genes to constitute a chromosome. A proper set of chromosomes, called population, undergoes the Darwinian processes of natural selection, mating and mutation, creating new generations, until it reaches the final optimal solution under the selective pressure of the desired fitness function.

GA optimisers, therefore, operate according to the following nine points:

1) encoding the solution parameters as genes;

2) creation of chromosomes as strings of genes;

3) initialisation of a starting population;

4) evaluation and assignment of fitness values to the individuals of the population;

5) reproduction by means of fitness-weighted selection of individuals belonging to the population;

6) recombination to produce recombined members;

7) mutation on the recombined members to produce the members of the next generation;

8) evaluation and assignment of fitness values to the individuals of the next generation;

9) convergence check.

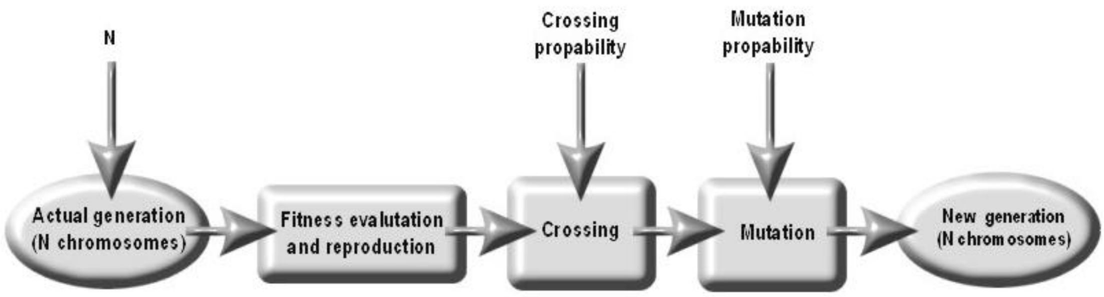

Fig.8 Base cycle of a genetic algorithm

The coding is a mapping from the parameter space to the chromosome space and it transforms the set of parameters, which is generally composed by real numbers, in a string characterized by a finite length. The parameters are coded into genes of the chromosome that allow the GA to evolve independently of the parameters themselves and therefore of the solution space.

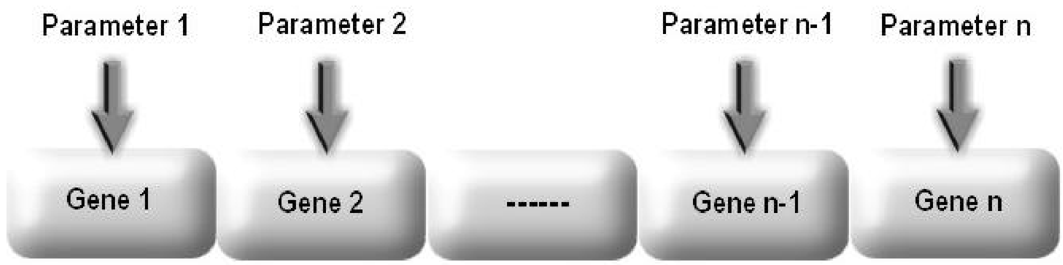

Fig.9 Encoding of the solution parameters as genes of a chromosome

Once created the chromosomes it is necessary choose the number of them which composes the initial population. This number strongly influences the efficiency of the algorithm in finding the optimal solution: a high number provides a better sampling of the solution space but slows the convergence. A good compromise consists in choosing a number of chromosomes varying between 5 and 10 times the number of bits in a chromosomes, even if in the most of situations, it is sufficient to use a population of 40-100 chromosomes and that does not depend of the length of the chromosome itself. The initial population can be chosen at random or it can be properly biased according to specific features of the considered problem.

Fitness function, or cost function, or object function provides a measure of the goodness of a given chromosome and therefore the goodness of an individual within a population. Since the fitness function acts on the parameters themselves, it is necessary to decode the genes composing a given chromosome to calculate the fitness function of a certain individual of the population.

The reproduction takes place utilising a proper selection strategy which uses the fitness function to choose a certain number of good candidates. The individuals are assigned a space of a roulette wheel that is proportional to they fitness: the higher the fitness, the larger is the space assigned on the wheel and the higher is the probability to be selected at every wheel tournament. The tournament process is repeated until a reproduced population of N individuals is formed.

The recombination process selects at random two individuals of the reproduced population, called parents, crossing them to generate two new individuals called children. The simplest technique is represented by the single-point crossover, where, if the crossover probability overcome a fixed threshold, a random location in the parent's chromosome is selected and the portion of the chromosome preceding the selected point is copied from parent A to child A, and from parent B to child B, while the portion of chromosome of parent A following the random selected point is placed in the corresponding positions in child B, and vice versa for the remaining portion of parent B chromosome.

If the crossover probability is below a fixed threshold, the whole chromosome of parent A is copied into child A, and the same happens for parent B and child B. The crossover is useful to rearrange genes to produce better combinations of them and therefore more fit individuals. The recombination process has shown to be very important and it has been found that it should be applied with a probability varying between 0.6 and 0.8 to obtain the best results.

The mutation is used to survey parts of the solution space that are not represented by the current population. If the mutation probability overcomes a fixed threshold, an element in the string composing the chromosome is chosen at random and it is changed from 1 to 0 or vice versa, depending of its initial value. To obtain good results, it has been shown that mutations must occur with a low probability varying between 0.01 and 0.1.

The converge check can use different criteria such as the absence of further improvements, the reaching of the desired goal or the reaching of a fixed maximum number of generations.

In our case it has been studied a very interesting genetic design solution that ensures cost reduction up to 70%.

It is now necessary to codify our design problem in a simple and efficient genetic problem.

First of all, once positioned the sensors on the plant, respecting all the safety/security goals, it is necessary to position the hubs and to decide at which hub must be connected each sensor. The number of hubs that must be used depends on the number of inputs of the hub themselves. A good choice consist in choosing a number of hubs so that the total of available inputs is almost 10% greater than the number of sensors, to allow the genetic algorithm to operate a better optimisation of the connections.

Once individuated the positions where it is possible to install the hub (this does not means that it is necessary to install an hub in that position, since it's installation need depends on the optimisation process), it is necessary to calculate the distance between each sensors and each hub and generate the so called *design connection table* where all the sensor-hub distances are properly reported. Since some connections are not possible, due to architectural restrictions that are particularly felt in historical buildings such as Corsini palace, the related situation is indicated with a X in the related position of the table. In table 1 an example of a 11 sensors-3 hubs design table is shown (a 6 inputs hub is supposed to be used so that the availability of 18 inputs is guaranteed).

	Hub 1	**Hub 2**	**Hub 3**
Sensor 1	4	X	20
Sensor 2	X	3	24
Sensor 3	7	4	2
Sensor 4	X	7	5
Sensor 5	2	5	X
Sensor 6	9	1	X
Sensor 7	14	7	3
Sensor 8	18	X	X
Sensor 9	X	4	15
Sensor 10	X	8	X
Sensor 11	6	X	5

Table 1: Example of a *design connection table*. A X means a not allowed connection between the sensor and the hub, while a number indicates the distance between the sensor and the hub expressed in meters.

Once derived the design connection table it is necessary to proceed with the codification of the design problem in a simple and efficient genetic problem.

The easier way to do this is to use a chromosome composed by a number of genes that is equal to the number of sensors: this means that the chromosome is composed by homogeneous genes. Each gene, related to a specific sensor, codifies the number of the hub where the sensor is connected: for this reason the value of this gene varies between 1 and the maximum number of hubs N_H^{MAX}. The number of the effective used hubs can obviously be lesser than the maximum number of hubs since it depends on the found optimisation solution.

To allow the maximum efficiency of the genetic process, the sensor / hub connections, represented as a numbers into the genes, are coded with a binary alphabet so that in the presence of the crossing and the mutation operation, the data can be exchanged at the inter-gene level more that at the intra-gene level. If N_H^{MAX} is the number of hubs that ought to be used (according to the criteria expressed above) the minimum number of bits necessary to codify N_H^{MAX} can be demonstrated to be:

$$\text{Int}(\log_2(N_H^{MAX})+1) \quad (1)$$

where Int () is the integer operator, that is an operator which rounds the argument () to the nearest integer towards infinity. In table 2 the codification of the gene is shown.

	Gene	Considered variable	Variability range	Variable type	Number of Bits
Chromosome	1	Sensor 1 / hub connection	1 ? N_H^{MAX}	Integer	Int ($\log_2$ (N_H^{MAX}) +1)
	2	Sensor 2 / hub connection	1 ? N_H^{MAX}	Integer	Int ($\log_2$ (N_H^{MAX}) +1)
	??????	??????	??????	??????	??????
	??????	??????	??????	??????	??????
	N_S -1	Sensor N_S – 1 / hub connection	1 ? N_H^{MAX}	Integer	Int ($\log_2$ (N_H^{MAX}) +1)
	N_S	Sensor N_S / hub connection	1 ? N_H^{MAX}	Integer	Int ($\log_2$ (N_H^{MAX}) +1)

Table 2: Details of the scheme of codification of the gene.

Once defined the chromosome as shown in table 2, an initial population of 40 chromosomes is randomly generated and let evolve according to the genetic scheme shown in fig.8.

In fig.10 three significant examples of chromosomes obtained during the evolution process are shown.

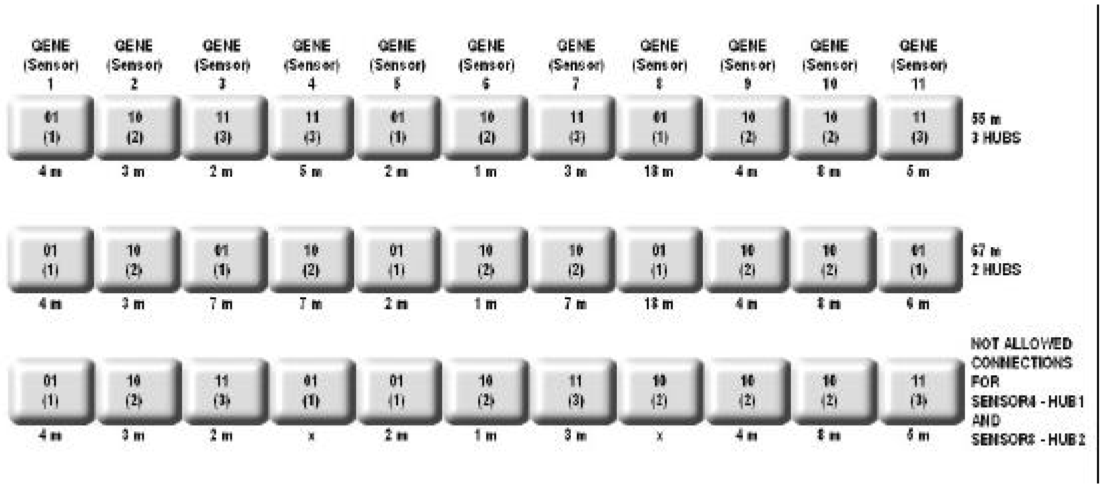

Fig. 10 Three significant examples of chromosomes obtained during the genetic evolution process.

The first chromosome represents the most efficient solution in term of shorter sum of connections between sensors and hubs (55 meters), as it is possible to verify from table 1, using anyway all the three hubs.

The second chromosome represents the most efficient solution in term of both number of hubs (2) and shorter sum of connections between sensors and hubs (67 meters): if the cost of the hub is higher than the cost of the difference of length of the connections (67-55=12 meters), this chromosome tends to extinct during the evolution while the first chromosome tends to dominate and to become the most numerous of the final population. If the mentioned cost is lower an opposite situation takes place.

The third chromosome represents a good solution in term of reduction of the sum of the length of connections with the only exception of genes 4 and 8 where the connections sensor 4 – hub 1 and sensor 8 – hub 2 are respectively attempted. Since these connections are not allowed, as it is possible to deduce from table 1, this chromosome immediately extinct at the first fitness evaluation process, because of its inadequacy to represent a valid solution for our problem.

The used GA ensures to obtain the most optimised solution as a function of the input parameters. The optimised solution is generally found after a certain number of cycles, called generations: this number has demonstrated to vary with the number of sensors, as shown in fig. 11.

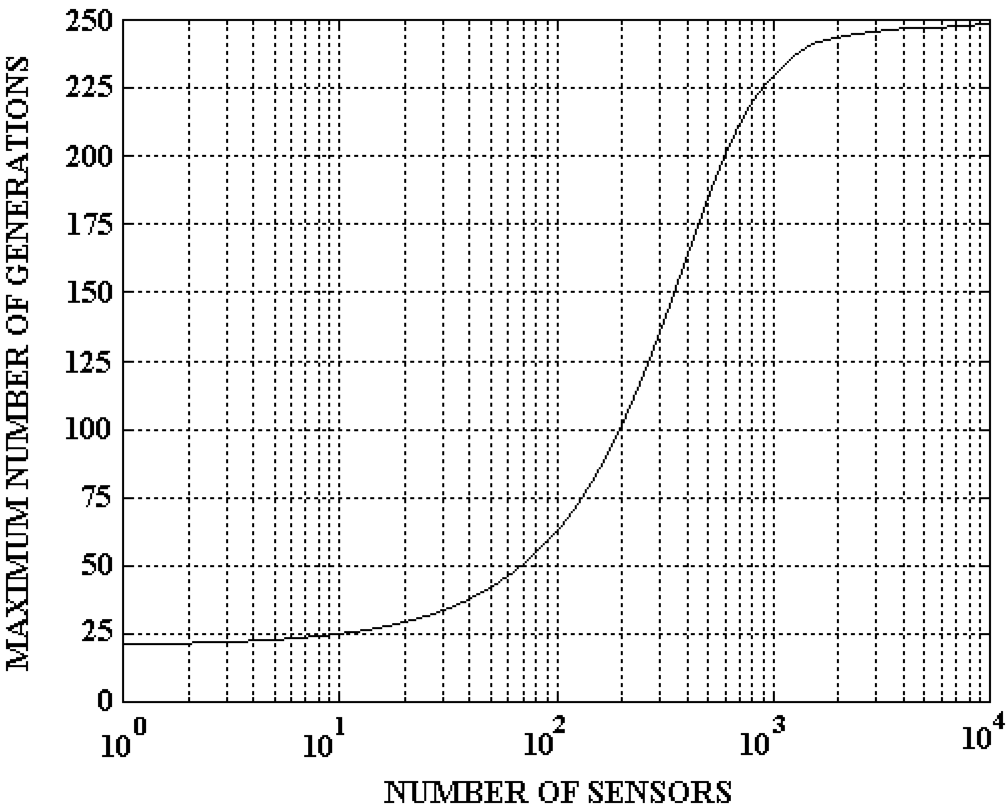

Fig. 11 Number of generations necessary to obtain the optimised solution as a function of the input sensors.

The important result of this genetic design method is represented by the cost reduction. In fig.12 the cost reduction of the installation (in percentage) as a function of the number of sensor is shown. The cost used as a base to calculate the cost reduction is represented by the most expensive solution, that is a solution found by means of another genetic algorithm that ensures to find the maximum cost.

It is interesting to note that the cost reduces with the number of sensors, that is the more complex is the installation and the greater is the cost reduction, since the GA optimisation is capable of showing all its efficiency on large scale.

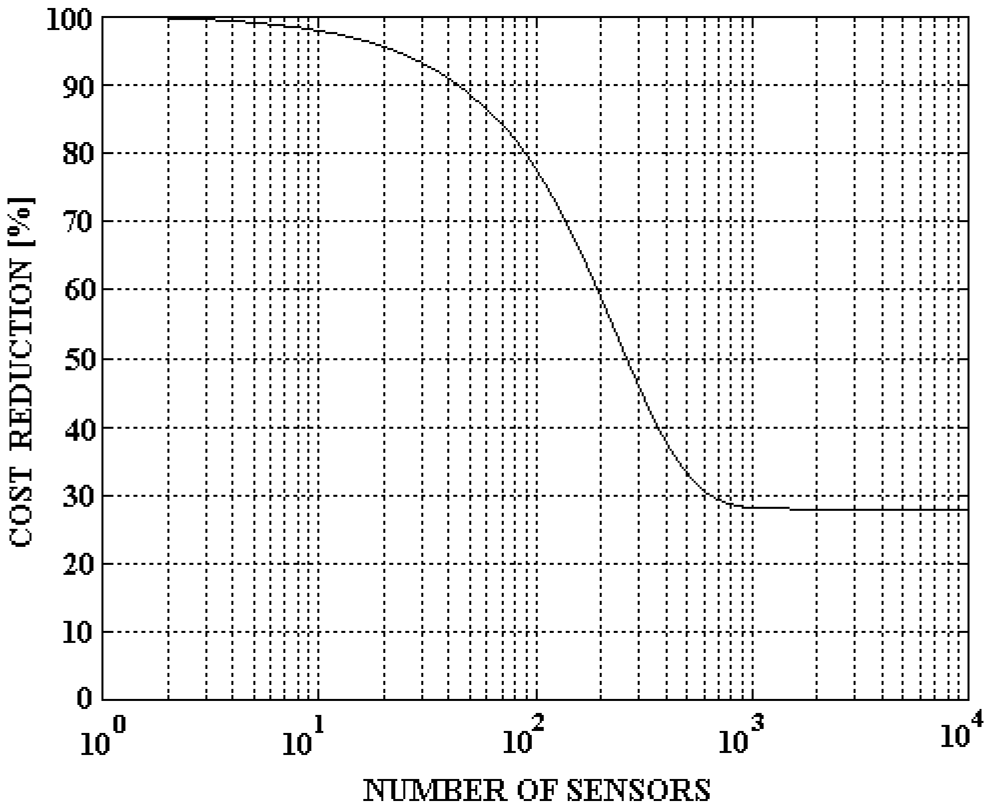

Fig. 12 Cost reduction of the installation (in percentage) as a function of the number of sensors.

3.4 THE SAFETY/SECURITY CONTROL PANELS

The safety/security control panels are endowed with one or more than one loop buses so that an increased liability results in the event of malfunctioning of one bus due to an interruption or to a short circuit of the connection wires: in this situation the related control panel loses the command of the only zone controlled by the damaged bus, continuing to work correctly on the other zones.

An efficient design criteria consists in dividing the zone to be controlled in a way that allows to use the maximum number of buses and in dividing the sensors and the hubs equally on all the buses. In this way it results an increased reliability since an eventual malfunctioning of one bus provokes the lost of control of a limited number of sensors and therefore of a limited safety/security zones.

The malfunctioning of one bus and of the related hubs is immediately signalled by the control panel locally and remotely by means of the supervision system.

All the control panels are equipped with a rechargeable battery that allows them to supply the whole installation, included the hubs and the sensors, even in the absence of the main supply, that is anyway guaranteed by means of a proper inverter supply. In this way a high level of reliability is guaranteed from the electrical power supply point of view.

All the control panels are installed in a proper secure and protected room and they communicate with the supervision system by means of proper communication ports that are connected to the communication network.

3.5 PERFORMANCES AND FUNCTIONALITIES OF THE INTEGRATED SYSTEM

We already said that the control units of the supervision system are represented by proper computerised consoles, that is a personal computer, equipped with graphical mapped programs which allows the control of the whole integrated safety/security system of the palace.

Due to the architecture of the system, it is possible to add or move in any moment a supervision console using the communication network or it is even possible to introduce remote console using internet: in this case the transmission velocity and the security level are unavoidably reduced due to the intrinsic features of internet itself.

The supervision system manages all the safety, security and emergency procedures, strongly simplifying the duties of the personnel, that hasn't to own, in this case, specific skills. In fact the system requests the action of the personnel only in a restricted number of critical events, driving its action by means of simplified graphical maps or easily understandable messages.

The integrated system ensures a high safety/security level to the people and to the books inside the library. In fact, if a fire or a dangerous situation is revealed, the system immediately signals it to the operator and activates the visualization of the zone interested by the alarm, using the nearby cameras and recording anyway the images coming from the not interested zones. Further the system executes the following procedures:

a) activation of the closer camera in case of an alarm signaling from the anti-intrusion installation or the fire signalling installation, showing the related images on a proper monitor and properly alerting the operator, recording the dangerous event passing from the time-lapse modality to the continuous modality, to avoid of losing any significant detail that could be useful to the reconstruction of an alarm generation sequence or of a criminal event;

b) emergency procedures activation in case of alarm signaling generated by the fire signaling installation, activating the closer camera to control the truth and the eventual magnitude of the alarm;

c) activation of fire extinguishing installation (if the system is enabled) or operator activation request, checking the eventual visitors presence inside the interested zone by means of the anti-intrusion installation;

d) automatic personnel call as a function of the kind of emergency;

and a lot of other functionalities which cannot be illustrated here for security reasons.

In reality, due to the high versatility, it is possible to integrate further functionalities in a second time, according to practical operative needs.

All the received signals and the operative actions on the installations are recorded by the supervision system, to constitute a central historical archive, that stores these significant data for an indefinite time.

The images coming from the video surveillance installation are deleted periodically using an overwriting policy that starts from the older images, while the most interesting images can be recorded on proper long term store media such as DVD, CD-ROM or tape.

The supervision system consoles have been optimised from the ergonomic point of view, properly disposing the different inputs and visualization devices, to ensure the maximum comfort of the operator.

The integrated safety/security system can be properly expanded at any time and interfaced with any device located at any distance.

3.6 CONCLUSION

It is always very important to use integrated safety/security systems to protect historical heritage, as been shown in this paper, illustrating the interesting application of the library of the "Accademia Nazionale dei Lincei" at Corsini Palace in Rome where a high number of ancient, rare and unique books, volumes, and manuscripts are present.

The designed and installed integrated safety/security system is capable of protecting the whole library, from fire, damaging, vandalism, thefts, and unwanted intrusions.

The system has been designed using the typical multidisciplinary approach of the safety and security engineering.

In particular the system has been designed using a very advanced technique based on genetic algorithm optimisation, that has demonstrated to be able of ensuring high performances of the system and a high reduction of the installation cost.

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MISSING–FIRE AND FIRE LOSS DATA IN HERITAGE AND CULTURAL BUILDINGS

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INTRODUCTION

From the outset it should be understood that the term 'cultural heritage' is used in this paper to describe not only buildings and structures designated by national authorities as being of historic or cultural interest but also any building whose design, construction or use makes it part of the wider cultural heritage of a nation, cultural group or region. This definition also includes buildings whose contents may be of greater importance than the building itself, for example, museums, galleries, libraries or archives.

Fire can cause the total destruction of a building and its contents in only a few hours; areas not directly damaged by flame or heat may be damaged by smoke, dirt and falling debris or by the huge volumes of water which may be used in fighting the fire. One threat, which cannot be over-stressed, is the potential loss of authenticity - which is, after all, the quality from which the importance of the cultural heritage flows.

ABSENCE OF HARD STATISTICAL EVIDENCE

One of the most important problems in raising the profile of the heritage fire issue is the almost total absence of any reliable statistical evidence (in any European country) of the exact number and type of buildings which are being destroyed.

The problem has been expressed in the following terms:

ˆ There are no uniform European fire statistics (There is little reliable official fire information outside UK and Sweden)

• Many countries publish no data at all

• UK statistics are generally accepted as most reliable, but even they do not include anything specific on historic buildings

• The problem was identified in the UK originally in1989 and was the subject of some work by the Fire Protection Association in 1993 by the FPA. Despite efforts by Historic Scotland, English Heritage and the two UK National Trusts little more has been done in the rest of Europe.

The most reliable, publicly available statistics specifically relating to heritage fires are probably those produced by the National Trust for England and Wales. Their fire advisor's statistics show that:

• The National Trust for England & Wales owns/ manages 7500 listed buildings
• Between 1992 and 1993 the Trust recorded 133 fires - an average of 44 per year
• Even these figures are considered by the Trust's Fire Advisor to reflect some degree of under reporting. (Of course, 99% of these fires resulted in little damage).
• Over past 20 years fires have caused major damage to five NT Grade I/II* buildings - including the total destruction of Uppark House.

HISTORIC SCOTLAND

The concerns expressed earlier resulted in Historic Scotland funding a database project, in collaboration with the Chief and Assistant Chief Fire Officers Association (Scotland), to try to determine the extent of the risk to heritage buildings.

This initiative, the Scottish historic buildings national fire database project, commenced in April 2002. English Heritage has recently started a similar project. (Chief and Assistant Chief Fire Officers Association Safety and Standards Committee, June 2002).

The project, which was trialled between 1999 and 2001 in one divisional area in Grampian and Strathclyde FBs, integrates the GIS and CD Rom

information on Historic Scotland's own data with information useful to the fire brigade in tackling an incident at one of the listed premises.
Historic Scotland also considers that the current statistical reporting form for fire incidents (Form FDR1) does not capture sufficient data to determine the extent of loss due to fire. They currently base their assessment of fires within listed buildings in Scotland on a combination of anecdotal evidence and ad hoc collection of press coverage on such incidents.

This suggests that in Scotland, there is an average of 12.5 serious fires in A and B grade buildings each year. Figures for the last ten years are:

1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
10	7	11	14	15	17	13	17	11	10	16

OTHER ON GOING WORK

The EU's Co-operation in Science and Technology (COST)17 programme includes the following work proposal:

1 DATA, LOSS STATISTICS AND EVALUATING RISKS

1.1. Data and Fabric analysis

1.1.1 Establish available information about the total number of cultural heritage buildings to be considered, their value in cultural and financial terms and the actual risks they are subjected to.

1.1.2 Compile available statistical data on the extent of the built heritage at risk

1.1.3 Identify, analyse, and report on minor fire incidents (where the fire is extinguished without fire brigade attendance, false alarms etc.)

The UK is participating in this programme which has began its work in December 2002. The Chair of the programme is Ingval Maxwell of Historic Scotland and the second UK delegate is the author who will chair WG2 (Available and Developing Technology).

DATA WHICH ARE NEEDED

In the UK, where virtually all fires in buildings are the subject of a fire brigade report, it has been suggested that the simplest way forward in the short term would be to include a 'heritage building' box in the appropriate report form. This has been suggested by the UK Fire Protection Association on a number of previous occasions and has been rejected on a variety of grounds, most notably, that it would be too difficult for a (sometimes) junior officer in charge of a fire brigade attendance to make a judgment on what is (or is not) a building of heritage value. In the opinion of the author, this argument is clearly specious for even incomplete statistics would be better than none at all and in the writer's experience of this field fire brigade junior officers are most unlikely to fail to recognise most heritage buildings. (True, some 'modern' listed buildings damaged by fire may well go unrecorded - but then some would say this may not such a bad thing!). It has also been argued that part time or volunteer service personnel would also be unable to make the necessary judgements. This is an even more outlandish suggestion as in the experience of the writer there are few fire fighters more aware of the buildings in their 'own areas than those who live and work in the areas they protect..

Work is also taken place on a collaborative base with English Heritage and the Chief and Assistant Chief Fire Officers' Association to emulate the successful Scottish pilot programme of providing fire appliances with a CD Rom containing information about the nature, construction and location of heritage buildings in specified areas. In the longer term, proper integration of the databases of the national heritage agencies with fire brigades own information systems would seem to offer the best options for all parties.

The US author Robert A Heinlein wrote that ‘if you can’t express it in numbers, it’s not fact but opinion’. Until we can fully understand the extent of the problems of fire loss in historic buildings we will continue to be expressing opinions when we should be stating facts.

SCHULT'Z HAZARD ANALYSIS (S.H.A.)

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S.H.A. assumes that the structure of a museum can be assimilated into a complex system.

"… in order to investigate conditions close to a point of balance… That is, to examine the state in which the non-balance can be source of order…".

"… a system is necessarily subject to instability. That is, self-organization is the exception not the rule …".

The typical aspect of **S.H.A**. is therefore the study of self-organization in non-balance systems; this study examines the role of BIFURCATIONS close to the so-called point of bifurcation. That is, the system "choose" one of the possible branches, but apparently nothing justifies the preference of any choice. Besides, it is necessary to consider that complex systems are able to preserve and to convey information.

In the case of our museum system it can be stated that:

a) Far from bifurcations deterministic equations are considerably sufficient.
b) Close to points of bifurcation elements become essential things.
c) Probability calculation deals with the regularity of events, but not with events themselves. Hence the same concept must be re-examined.
d) Events are the initial conditions on which probability calculation cannot make any statement, but it can only assign a probability to every possible initial condition.
e) Once the initial condition has been defined, the system will be pushed toward its most probable state through an irreversible process.

The study of possible solutions, which should have specific conditions, is considered, according to **S.H.A.**, a possible way. Infact, as we know, every System produces "spontaneously" a factor that plays somehow an "upsetting" role. The main difference here is that the "upsetting" has been produced by the system itself.

According to us the distribution of fluctuation probabilities depends on their dimensions and on system conditions.

Infact, on a small enough scale we obtain a distribution close to Poisson, whereas, with a rising interval, the fluctuations departs from a Poisson's distribution. Besides instability, statistic fluctuations rise, given time, and eventually push average values toward their new state. When this law has been satisfied, the AVERAGE provides an adequate system description, but vice versa averages have been driven by fluctuations. In this case it is necessary to refer to the Markov chains, such as expression of the "big numbers law" collapse.
That means that the binominal distribution and Poisson arise usually in questions that involve repeated independent events with two only possible results deriving from any trial, and having the same probability over the whole trials. Gauss's distribution comes after the "big numbers law" application.

Hence, from a methodical point of view **S.H.A.** firstly individuated the VARIABLES of our model and, above all, examined the way in which the system develops or achieves a stationary state for a period of time long enough. Secondly, it was necessary to examine variations coming from random or systematic variations.

As a result of that a **1st consideration** can be obtained:

"… system evolution depends on a certain quantity of parameters … a few of these can have continuous and even sudden changes … at any case

variations of parameters generally changes the structure of equations … increasing system freedom degrees …".

The **<u>2nd consideration</u>** that can be made is the following one:

*" … system properties depend on a set of parameters **<u>n</u>**. In a system involving two variables **<u>x</u>** and **y**, these one work by functions which clearly depend on **<u>n</u>**. … A light variation of **<u>n</u>** as to **<u>n1</u>** turns into qualitatively different trajectories … Consequently **<u>n=n1</u>** is a point of bifurcation … That means that complex behaviours can arise from relatively simple systems, like those with two variable …".*

The **<u>3rd consideration</u>** that can be made is the following one:

*" … a very interesting aspect regards the point where the parameter of bifurcation **<u>l</u>** meets the critical value **<u>ln</u>** … giving rise to a **<u>limit-cycle</u>** … That is, in this case, the system which evolves according to several temporal scales … That means that in these systems one or more steps of the frequency … move very quickly in comparison to others …".*

The **<u>4th consideration</u>** that can be made is the following one:

" …in systems, amplitude and periods are determined by the essential conditions … whereas the configuration has been determined by the system itself … The fact that mechanism of bifurcation is characterised by the break of symmetry constitutes a property…".

The **<u>5th consideration</u>** that can be made is the following one:

" … systems assume the existence of many freedom levels, which involves automatically the appearance of some fluctuations … they can come to the observer as casual events … and the system replies to them according to definite laws … When small fluctuations are amplified, these can just push the system toward a new phase… It is also certain that the

constrictions, maintaining the system in a state far from the point of balance, affect the behaviour of fluctuations …".

The **<u>6th consideration</u>** that can be made is the following one:

" … considering the huge reduction of freedom degrees next to the first bifurcation, which means that the first bifurcation is dominated by one spatial way or by one temporal frequency … but it confers on system high sensitivity …".

The **<u>7th consideration</u>** that can be made is the following one:

" … before bifurcation the variance tends to diverge according to the inverse power of distance from the point of bifurcation … ".

According to **S.H.A.** systems involving more than one variable, and working far from the point of balance, such as those related to museums, the classic function:

R = P x M

should be considered **<u>no longer adequate</u>** as:

- ?? Bifurcations can take place with a single variable
- ?? The variability of fluctuations changes according to their scale growing
- ?? The probability of transition is a non-linear function of stochastic variables
- ?? Results cannot be extended as the system answer changes
- ?? Because of fluctuations the system can alter the laws of evolution.

Hence, from systems with more than one variable it is possible to get several types of bifurcation, which lead to unusual trajectories.

<u>According to S.H.A. a few remarks should be made about the following issues:</u>

a) The probability of having a particular fluctuation in a complex system
b) The probability that this fluctuation will get amplitude and a significant interval.

At the same time Schult'z attention has been concentrated on museum system evolution in a graphic representation. This project takes into account that:

?? Close to the critical point the system gets into an unstable zone, the trajectory is encircled by a limit-cycle
?? Far from the critical point the trajectory becomes a stable knot
?? Trajectory oscillations correspond to the behaviour of the system
?? The system is characterized by as many limit-cycles as its fluctuations are.

Therefore, the basic concept that I would like to underline in this meeting regards our museum system POINT OF BALANCE, because:

?? Instability is caused by non-balance environmental conditions, which favour new instability appearance
?? Irreversible processes are distance from the system state of balance
?? A balanced system is a system when fluctuations are damped
?? More a system results a complex one, more interactive functions can be found
?? Marginal stability in the point of bifurcation will decay for t = 8 .

According to us, this concept exceeds the already basilar SELF-ORGANIZATION principle in which non-linear processes and non-balance conditions have a significant role.

BUILDING AND RESTORATION SITES FIRE: STATISTICAL DATA FROM A 6 YEARS EXPERIENCE IN VENICE

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ABSTRACT

The problem of restoration sites fire and their consequent great damages to the historic-artistic heritage in our country, does not receive the just attention yet.

That is probably because of lack of adequate information, which would allow such a reality emerge and enable to establish the necessary landmark upon which the consequent initiatives are to be organized.

The present contribution, which represents a part of a research work still in progress Venice University Institute of Architecture (I.U.A.V. – Istituto Universitario di Arhitettura di Venezia), aims to begin filling up that gap through the data analysis provided by the Firemen operating in Venice, where, because of building fabric typology existing there, every of its building sites can be identified as "restoration site".

Keywords: Restoration sites fire, fire risk indicators, safety operational plan

INTRODUCTION

The big fires occurred in our country in the last years, have awaken the public opinion's interest in the artistic and cultural heritage vulnerability to such events.

Their outcomes have, on the other hand, resulted being greatly enlarged by the conditions of the urban context in which they occurred, which have contributed to increase their magnitude because of the way fires themselves have been able to easily spread throughout an urban building fabric mainly realized of combustible materials.

In many of those circumstances, the presence of a building site had not at all been taken into due consideration, even though it had "contributed in a significant way to magnify the consequences, as it had involved the reduction of the safety level” [1].

Fire, as well as other aspects of safety at a building site, is specifically dealt with in an extensive and articulate framework, which in our country refers to Legislative Decree 494/94 enforcement of Council Directive 92/57/EEC of 24 June 1992 on the implementation of minimum safety and health requirements at temporary or mobile work sites.

When enforcing that regulation, it is often interpreted only in the light of the more frequent accidents occurred at building sites, whilst fire itself is almost never taken into consideration except in very particular cases or by Supervising Authorities’ specific imposition.

Purpose of the present contribution is to allow this problem emerge through the data analysis extrapolated from Venice Firemen’s reports in a 6-year period, from 1997 to 2002, while trying to extrapolate from it any useful information upon which starting to structure operating suggestions for the management of this building process phase.

Photo n. 1 - In the night between 12 and 13 December 1996 a fire destroyed great part of the Great Theatre "The Fenice", in Venice. In this case a temporary alteration caused by the construction site has contributed to spread fire and hindered the operations of firemen teams'.

The case analysis

The Firemen's intervention report forms are structured so that a wide typology of interventions associated to as many specific numerical codes is taken into consideration; datas containg many and complexes information concerning tasks which often exceed "simple" fire extinguishing.

From these reports have been extracted and elaborated more significant information which are important for this contribution.

A first information can be obtained by comparing the quantity of building sites fire interventions with the total amount of general kind ones and the number of "potential" building sites extrapolated from the "authorisation acts" adopted in Venice at the time (table 1).

Table 1: Comparison between fire intervention and "authorisation acts" adopted

Year	**Tot. Fire**	**Tot. Fire in Construction site**	**Tot. Authorization Acts**
1997	133	20	1.857
1998	116	31	2.276
1999	137	19	1.972
2000	146	7	2.094
2001	138	18	2.176
2002	193	11	2.574

The data about the possible fire starting sources, codified under the heading "alleged causes", and those about the materials having contributed to the combustion process, available under "substances and materials involved" (Figure 1 and 2).

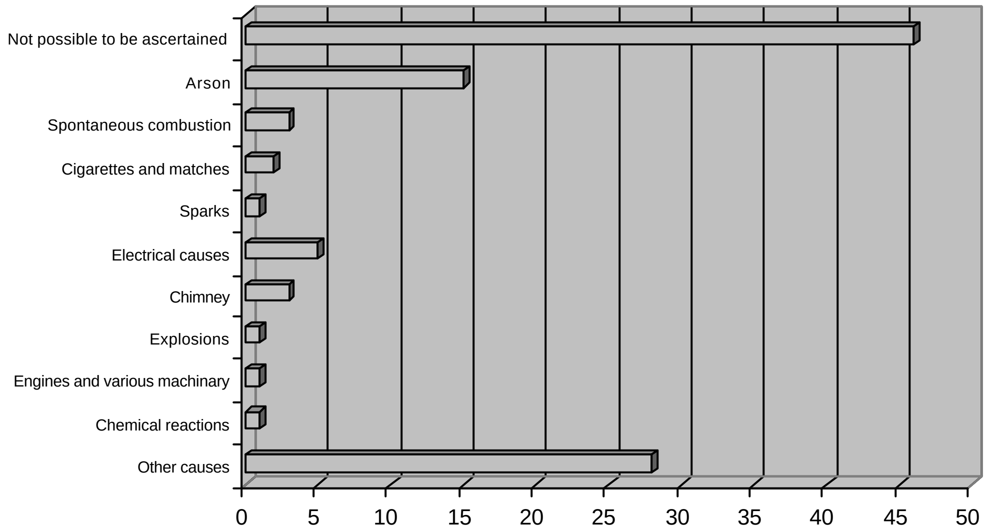

Figure 1. "Alleged causes" and consequent intervention frequency.

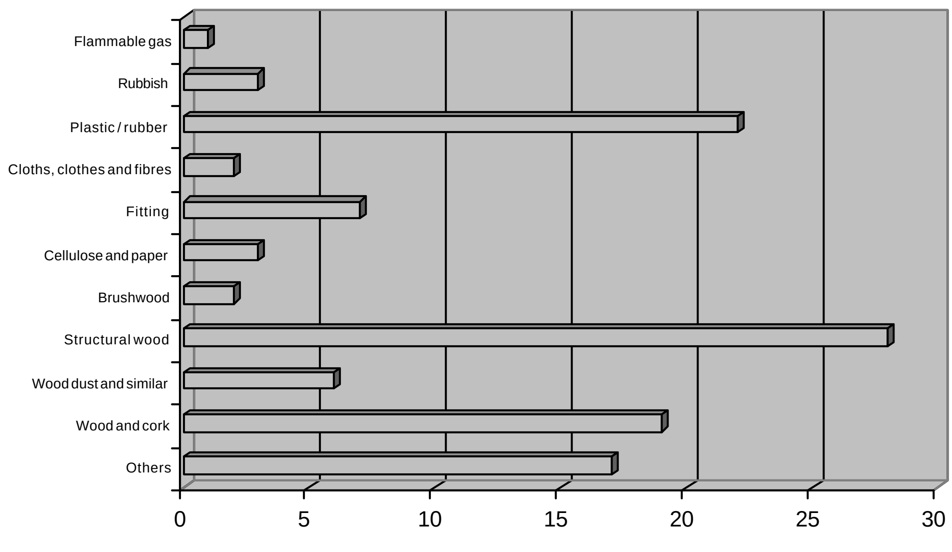

Figure 2. “Substances and materials involved” and consequent intervention frequency (Under the category "plastic/rubber" are included the protection covers made of combustible materials and the building site enclosures).

Photo n. 2 - Venice, 27 june 1998: fire in the outside of Santi Geremia e Lucia's church. In this case the scaffolding contributed to accelerate the fire spread .

The intervention lengths of time allow to trace the events gravity (Figure 3).

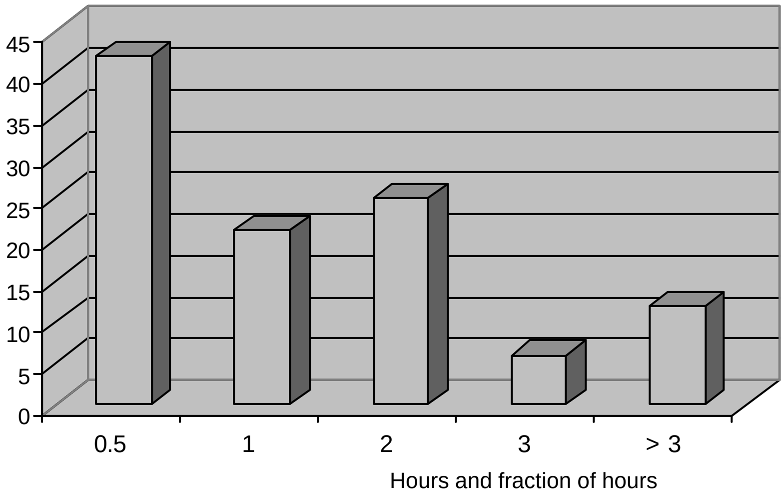

Figure 3. Intervention frequency and their duration (in hours and fraction of hour)

The following graph illustrates the data concerning the Firemen teams' lead-times taken to get to the fire-site.

In a particularly sensitive context such as the one taken into consideration, the guarantee of short travelling times becomes of significant relevance in order to contain the possible outcomes of a fire and, more generally speaking, to guarantee an efficient public rescue service (Figure 4).

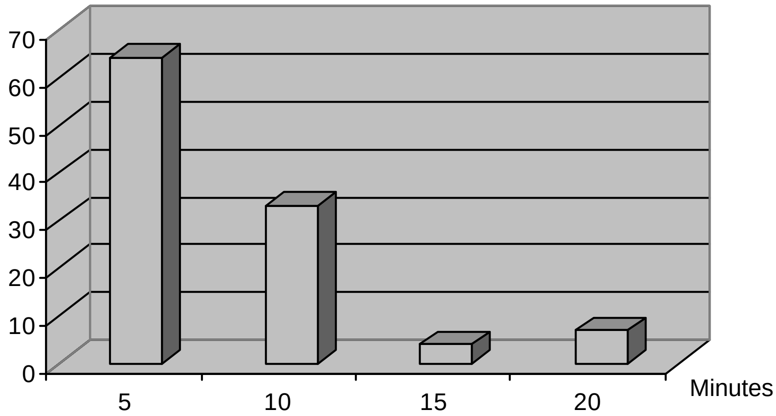

Figure 4. Distribution of the firemen teams' lead-time taken to get to the fire site.

Next survey concerns the intervention frequency in connection with the hour (figure 5) and week-day (figure 6), that shows how such events occur mainly during the building site closing hours.

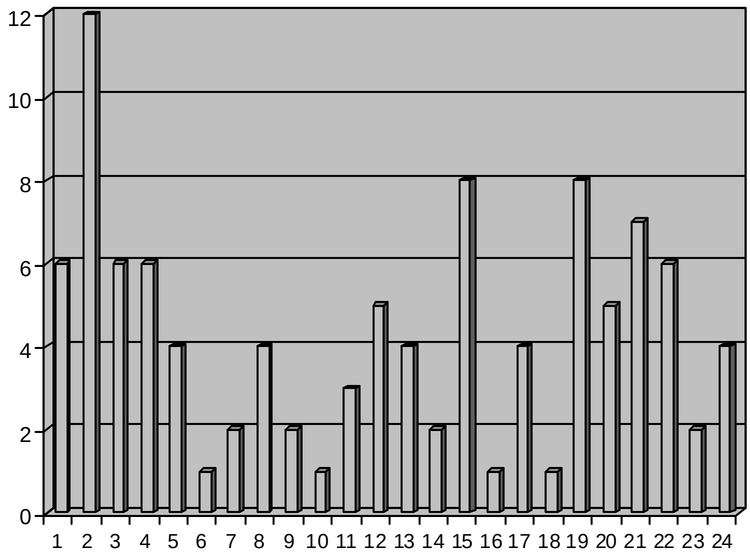

Figure 5. Amount of interventions in the hour of the day

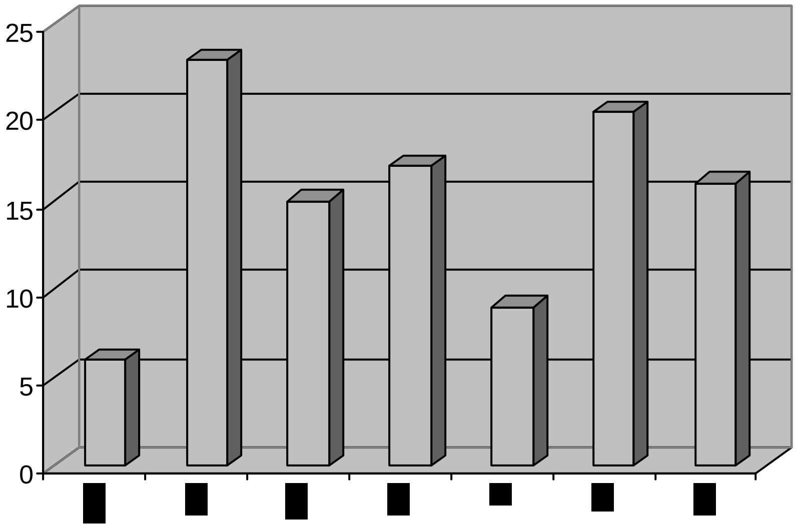

Figure 6. Amount of interventions in the week-day

This last aspect may be considered with particular attention as it highlights, at least according to the available data, a circumstance increasing the building site vulnerability.

Both Fenice's in Venice and Dome's in Turin fires have occurred at night-time; from the investigation acts emerge that in the latter of these two circumstances "… it seems there has been a 40-minutes interval between the first detection of fire and the call for help to the Firemen in Turin. That is not the first case in which a premonitory sign (such as the sighting or detection of smoke) are initially underestimated" [2].

THE UNDERTAKEN INITIATIVES

The problem sofar analysed has been partly tackled within the Department for the Architecture Construction (Dipartimento per la Costruzione dell'Architettura) of Venice University Institute of Architecture (I.U.A.V. – Istituto Universitario di Arhitettura di Venezia) in prof. Piero Michelotto's course and with this presentation writer's contribution.

The therefrom obtained result is the arrangement of a fire risk analysis route, which is still in progress at present, and which target is to identify the critical phases in the management of a building site starting with the elements peculiar to the determination of the structure vulnerability and subsequently continuing with the identification of the single phases or building processes which the specific technical directions about the execution modalities.

On the table the “structure + construction site” complex is to be put for evaluation, and not the two situation separately, that is a remark which may seem taken for granted or trite, but it is instead to be considered with due attention.

Many are the conditions that contribute to identify the fire risk indicators peculiar to that complex (iRt): the environment (iRen), the construction site (iRcs), which on the other hand aspects connected with its organizational and management complexity are correlated to, the works (iRwk) and their coordination (iRco).

It is this a route that will allow to acquire useful directions to revise those work procedures connected with fire risk, that are to be included in the Safety Operational Plan.

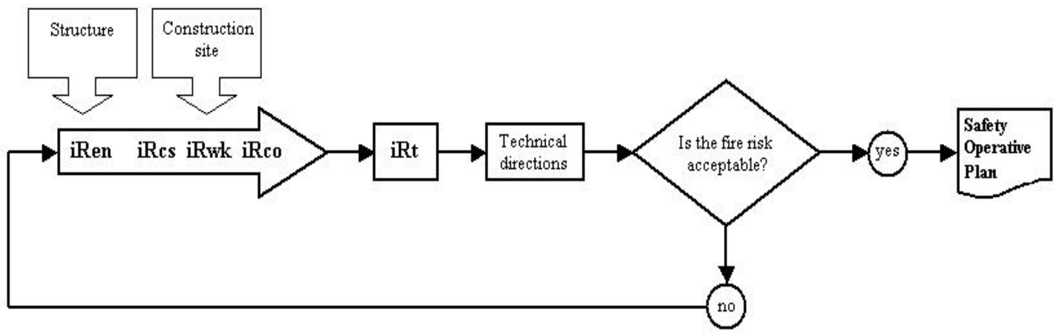

Figure 7. Scheme of procedure for fire risk indicators assessment in “structure + construction site” complex.

CONCLUSION

From what just illustrated in this presentation it clearly emerges how, during the execution of extraordinary works, or however during building site setting up, the fire risk increases considerably in consideration of the changed risk conditions of the places, the use of building sites materials, which are usually combustible, and the reduction (if not the cancellation) of fire-fighting defences.

It is therefore important to tackle the problem since the planning phases of the building site itself, putting it strictly in connection with the conditions peculiar to the structure and the environment context considering with attention also the possibility of Firemen Teams' intervention.

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COST ACTION C17: "BUILT HERITAGE: FIRE LOSS TO HISTORIC BUILDINGS – THE CHALLENGE BEFORE US"

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ABSTRACT

The current high level of loss of historic buildings to the effects of fire is a cause for significant concern. With a greater awareness of the issues involved, and the increased adoption and utilisation of modern fire-fighting technology, this can be combated and reduced. However, the installation of fire protection measures, as with all conservation work, should best follow the principle of minimum intervention. Schemes should be specifically tailored for each buildings need, taking into account its importance, function, character, construction, finishes and detail.

Historic buildings are a finite resource, and their loss to the effects of fire is an issue of international importance. The intention of "COST Action C17: Built Heritage: Fire Loss to Historic Buildings" is to investigate the consequences of the significant physical cultural loss of Europe's built heritage to the damaging effects of fire. Initiated in December 2002 this four-year programme will be achieved in a multi-disciplinary, multi-national manner through the collaboration and integration of a variety of related projects and partnership country interests. It will also build upon the range of current research initiatives, and recently published associated material. The outcomes will be the promotion of data and information on methodologies and management systems. This will assist a wide range of end-users balance fire engineering needs with conservation requirements in the future preservation of European patrimony.

Keywords

COST; Fire loss; Historic Buildings.

THE HISTORIC PERSPECTIVE

Historically, fire fighting has been a feature of architects' thinking since the mid-18th Century. Ornamental ponds that served as landscape features provided fire fighting water supplies near mansion houses, and various devices were contrived to effect escape from buildings in an emergency. But essentially primitive ladders, hoses and pumps, sand buckets, and water bucket chains were relied upon to control any fire that broke out. The alternative was to let the fire burn itself out, leading to the loss of building and contents.

Whilst modern fire protection installations can readily be designed to be technically efficient, there is a tendency for many systems to be less than sympathetic in their appearance following installation in a sensitive historic building interior. This is largely because the engineering design profession and manufacturers do not think laterally about the conservation issues that are involved. As result suppliers tend to offer limited options in the choice of available equipment. Equally, architects and designers do not fully understand the complexities and sensitivities of the issues involved and, in consequence, the internal appearance of important buildings frequently suffers as a result of insensitive detailing.

Although retrofit detection schemes are considered and implemented, more often than not, a holistic approach is left unresolved - with the building being offered little or no suppression protection. To be more effective, the need is for owner, architect, engineer, contractor and supplier to be more in tune with the degree of risk, and the physical and aesthetic attributes of what needs to be protected. All professional interests must learn to work towards achieving a better balance in the final results and this ideal is behind the COST C17 project.

PROMOTING THE AWARENESS OF HERITAGE FIRE LOSSES

Based on a translation of the German work “Brandschutz in der Altstadt” the FPA edition of “Fire Protection in Old Buildings and Town Centres” in 1992 illustrated the special dangers of fire in historic buildings and towns and showed what measures were appropriate for dealing with them. It specifically targeted building professionals involved in modernisation and repair works, and did much to increase an awareness of how fires could be avoided.

The FPA publication “Heritage under Fire”, originally published in 1990 and enhanced by a second edition in 1995, also provided valuable information to those responsible for implementing measures to counteract the effects of fire. Through a dramatic series of case studies, the publication brought into a sharp visual perspective the impact of heritage fire loss. Whilst at the time this document was an essential reference work, it has become outdated.

The 1994 NFPA publication “Recommended Practice for Fire Protection in Historic Structures” also did much to explore the technicalities of preventing historic building loss to fire and promoted a wide-ranging series of appropriate recommendations and effective practice. Perhaps given its provenance, the emphasis was inevitably placed on what might be described as “modern” buildings from a European perspective.

With the intention of disseminating information on research and providing guidance to those concerned with historic buildings fire safety, English Heritage published the following material during 1997 and 1998:

?? Timber panelled doors and fire
?? The use of intumescent products in historic buildings
?? Fire safety management in cathedrals
?? Prevention of loss or damage by fire in cathedrals
?? Smoke detection systems for cathedrals

Figure 1 Cowgate, Edinburgh. 8-10 December 2002. 11 building destroyed in blaze in the centre of the World Heritage Site, Unknown cause, but probably an electrical fault.

CAUSES OF FIRE

It is necessary to be precise when analysing the cause of a fire incident in a historic building to help get a broader picture of the types of causes that are most prevalent. This is required to formulate an appropriate response to stemming the scale of the loss levels. As a result, broad categories of cause can be identified:

- ?? electrical faults
- ?? open fires and defective flues
- ?? building maintenance work
- ?? vandalism
- ?? arson
- ?? smoking
- ?? lightning strike
- ?? accident

Taking into account traditional building construction, supplementary factors contributing to the spread of fire in a historic building can also be identified as being:

- ?? open and ill-fitting doors

- ?? thin wall construction
- ?? structural discontinuity
- ?? unknown wall and floor voids
- ?? unstopped ventilation and service routes
- ?? roof voids and lack of compartmentation

Overcoming the integration of these problems need to be addressed in a framework that gives equal weight to conservation needs and fire engineering thinking. Balancing all the conflicting issues is necessary to ensure that the best possible solution can be achieved. This is the fundamental thinking behind the COST Action C17 approach. However, during the 4 years of the Actions' life, much needs to be done to create a meaningful impact.

FIRE ENGINEERING AND CONSERVATION NEEDS

When designing and inserting an improvement on the level of fire protection in a historic building, a balance must always be struck to ensure that the significance and authenticity of the original building or site is retained (these are, after all, the special qualities we value). Minimal intervention should be a key principal to guide any new or retrofit work. In consequence, works to improve compartmentation, or to provide fire detection or suppression, should not cause unnecessary disruption or damage during installation, maintenance or eventual removal and replacement. Ideally, work should be designed and executed on a totally reversible basis, adopting a "plug in-plug out" philosophy. But, realistically, installing any systems or new equipment will create a physical demand on the building fabric. This will vary dependent upon the type and scale of the retrofit, and the intended functions that the building will have to accommodate.

With traditional building construction, some room for manoeuvre does exist in the hidden voids that, perversely, increase the risk in the first place. It should be possible to thread, service runs of flexible electrical supply, detection and monitoring cables, and air sampling tubes through the hidden voids to cause little damage, although careful planning and detailed site supervision will be called for in advance to ensure that they are also fire-stopped. It is recognised that the sensitive positioning of exposed detection equipment and associated apparatus in aesthetically and historically important interiors can be difficult to decide upon, and requires detailed guidance. Sharing knowledge on how others have addressed and overcome such problems is another objective of the COST Action.

Looking at the topic from two different perspectives, from the Fire Engineering point of view there will be a desire to accommodate:

- ?? life safety provisions
- ?? fire safety management and prevention
- ?? detection and alarm systems
- ?? means of escape
- ?? control of fire growth and spread
- ?? structural stability
- ?? smoke control
- ?? fire fighting access

From the conservation perspective, it will be necessary to consider the preservation of the buildings:

- ?? form and layout
- ?? age and value
- ?? occupancy and use
- ?? location and character of internal spaces
- ?? quality and importance of finishes
- ?? contents
- ?? site location and accessibility

At the heart of the COST C17 Memorandum of Understanding is the desire to work towards an integrated policy that balances fire engineering and conservation needs which have joint regard for the-

- protection of life
- protection of the building, its finishes and contents
- routine training of staff and promotion of awareness
- highest standard of risk management

Figure 2 Bower Building, University of Glasgow. 24 November 2001. Category A Listed building extensively damaged with an estimated £7 million loss. Many historic books also lost. Cause unknown, but thought to have started by fireworks.

HISTORIC SCOTLAND'S FIRE RESEARCH PROGRAMME

Historic Scotland initiated research into the protection of historic buildings from fire in 1994. The overall aim of the programme was to ensure that measures required to protect occupants, users, and the fabric of historic buildings are appropriate, consistent with conservation principles, and make the best use of the available resources. This work has been supported by an industry-wide Scottish Historic Buildings Fire Liaison Group. The Group convenes, as necessary, to discuss matters of mutual interest, and has advised on the development and drafting of pragmatic published technical guidance.

TAN 11: FIRE PROTECTION MEASURES IN SCOTTISH HISTORIC BUILDINGS

Specifically examining the integration of fire engineering and conservation related issues the intention of Technical Advice Note 11 was to offer a practical guidance for dissemination amongst those responsible for the nation's historic structures. Released in September 1997, it summarised the available literature and the problems of working with respect for historic building details in effecting retrofit schemes.

TAN 14: INSTALLATION OF SPRINKLER SYSTEMS IN HISTORIC BUILDINGS

The second technical publication on fire related topics to be produced by Historic Scotland's TCRE Group considered the appropriateness of sprinkler systems in more detail. This aimed to develop a more focused awareness of the problems, and the benefits of installing suppression systems in sensitive interiors.

The foundation for the Advice Note lay in Historic Scotland's own experience, in 1994, of installing detection and a fully-charged water sprinkler system in Duff House, dating to 1735, on the outskirts of Banff, in north-east Scotland. This was the first fully comprehensive installation of its kind in the United Kingdom.

TAN 22: FIRE RISK MANAGEMENT IN HERITAGE BUILDINGS

Under current UK legislation, a life safety fire risk assessment is legally required to be undertaken for all workplaces and must be kept up-to-date to ensure protection for occupants and users. Released in 2001, TAN 22 is the latest fire-related technical advice note to be published by Historic Scotland. Being complimentary to the two previous notes, it shifts the focus in offering management guidance on the protection of culturally significant buildings and their contents.

SCOTTISH HISTORIC BUILDINGS NATIONAL FIRE DATABASE PROJECT

Following a practical demonstration of the results of a pilot project carried out by Strathclyde Fire Brigade East Command in 1998 and the examination of descriptive data contained in Historic Scotland's Listed Buildings CD-ROM, agreement was reached on the need to create a National Fire Database. This aims to present operational fire-fighters with up-to-date computerised information on what is at risk from the effects of fire in Scotland's Category A listed buildings, and to create a reporting mechanism for the gathering of accurate statistics on fires in historic buildings.

The Chief and Assistant Chief Fire Officers Association Fire Safety and Operations Committees endorsed the project intentions and encouraged its development. A Minute of Agreement was subsequently drawn up and initiated in 2002 between Historic Scotland and Grampian Fire Brigade on behalf of the eight Scottish Fire Brigades who will participate in completing the project over the next 3 years.

WHY A COST ACTION ON THIS TOPIC

In addition to associated levels of life loss, the number, authenticity and quality of European historic buildings is being steadily eroded through the effects of fire. In 1983 this was recognised by the Council of Europe Committee of Ministers, who recommended '*That the governments of the member states adopt all legislative, administrative, financial, educational and other appropriate measures'* to protect the built heritage from fire and other natural disasters.

Despite all the technical guidance that has already been produced, there is a need to find a balance between technological and management solutions to counter these disastrous effects. Across Europe the real scale of loss of historic buildings to fire is unknown, but superficial data suggests that the annual and aggregated effect is considerable, perhaps as high as one important historic building each day. There is a general lack of statistical information, and a common lack of understanding and appreciation of what measures are available and required, to counter the effects of fire.

The term “historic building” should be taken to be synonymous with the entire architectural heritage - comprising monuments, groups of buildings and sites, as well as movable objects having particular historical or aesthetic association with the protected building. There are a considerable number of historic buildings requiring protection. It is important to recognise that these structures are a major contributor to the ‘sense of place’ and recent research indicates that they are of great importance to both inhabitants and tourists. In some countries, the most important historic buildings are included on statutory lists, but those that are listed form only a small percentage of the total number that can be considered as part of the built heritage.

To be effective in the resolution of the degree of loss, the requirement is to develop a high level of international co-ordination, and strengthen the levels of trans-national multi-disciplinary co-operation. The need is to exchange and enhance experiences to increase awareness and understanding, and to focus future action. The associated skill and knowledge needs to be pooled, assessed and best practice developed. The underlying objective must be to retain the remaining cultural built heritage in an authentic state for future availability, access and enjoyment by all.

COST C17 WORKING GROUP ACTIVITIES

With a commitment to strengthen trans-national co-operation in the field, “COST Action C17 Built Heritage: Fire Loss to Historic Buildings” will exchange and enhance experiences to increase awareness in addressing the issues. It will also pool skills to develop and promote best practice.

Whilst additional Working Groups may have to be established during the course of the Action, the initial Four groups will address the following matters:

WORKING GROUP 1: DATA, LOSS STATISTICS AND EVALUATING RISKS

1.1 Data and Fabric analysis

1. Establish available information about the total number of cultural heritage buildings to be considered, their value in cultural and financial terms and the actual risks they are subjected to
   ?? *Make contact, in all member countries, with government departments responsible for listing cultural heritage to establish:*
      ?? *Number of listed buildings*
      ?? *Criteria for listing*
   ?? *Make contact with co-ordinating bodies for buildings insurance in each member country to establish the cost of losses to the cultural heritage*

2. Compile available statistical data on the extent of the built heritage at risk
   ?? *Action point to be progressed once data is gathered*

3. Balance the impact of physical interventions and of potential fire damage with the "value" and "significance" of the site
   ?? *Establish detailed case studies from each member country e.g. December 2002 fires in Edinburgh, Scotland and Trondheim, Norway.*

4. Identify, analyse, and report on minor fire incidents (where the fire is extinguished without fire brigade attendance, false alarms etc.).
   ?? *Identify reporting mechanisms for fires in each member country to test feasibility of getting comprehensive statistics on minor fires.*

- ?? *If not available, gather case study data from each member country*

1.2 Qualitative Risk analysis

1 Establish common definitions of terms to be used

- ?? *Draw up list of terms to be defined*
- ?? *Gather authoritative definitions of each term as used in each member country*

2 Investigate the history, (and relevant advantages and disadvantages) of buildings with different types of structure and materials and of installing detection and suppression systems in historic properties. Evaluate the risks involved and issues of risk transference.

- ?? *Order gathered case studies by construction type and date and fire protection systems installed.*
- ?? *Seek additional case studies for any identified gaps*

3 Establish a well-documented survey of the degree of existing usage

- ?? *Prepare questionnaire for listed properties in each member country*
- ?? *In Scotland the developing Fire Database will include information on fire protection measures in Category A listed buildings*

4 Establish a common risk assessment methodology, following a critical review of existing methodologies

- ?? *TAN 22 Fire Risk Management in Heritage Buildings provides a basis from which to work.*
- ?? *Gather best practice from member countries*

5 Consider remoteness of sites and compile an understanding of the impact of response time “delay” factors

- ?? *Identify case studies of remote buildings*
- ?? *Liaise with fire brigades regarding response times and consequent increased risks*

WORKING GROUP 2: AVAILABLE AND DEVELOPING TECHNOLOGY

2.1 Available technology (Fabric and materials)

1 Establish how historic building construction and traditional materials actually perform under fire conditions, when compared to statutory obligations.

- ?? *Modelling fire behaviour*
- ?? *Gather data*
- ?? *Fire Tech questionnaire results*

2 Consider how to obtain a balance between technological and management solutions to counter the effects of fire

- ?? *Establish criteria for decision making, these may include:*
  - ?? *Physical impact on a building*
  - ?? *Cost and reliability*
- ?? *Work through decision making for a number of properties based on criteria*

3 Consider the provision of available traditional skills and materials that will be required in post-fire situations.

- ?? *Conservation Register in Scotland - are their similar databases in other member countries?*
- ?? *Seek figures for total heritage spend per year in each member country*

4 Promote research into the consequences of fires and the causes of fires common and how well the building and its construction performed under fire conditions

?? *English Heritage Fire Research Database - assess current research initiatives*

?? *Seek information on current research initiatives in each member country*

5 Re-consider appropriateness of applying current codes, standards and risk assessment methods to heritage properties. In particular, consider the application of fire engineering techniques and performance standards to historic buildings.

?? *Fire Tech questionnaire results*

?? *English Heritage document on Fire Engineering for Historic Buildings*

?? *Case studies of sites where fire engineering principles have been used in heritage properties.*

6 Assess provision of means of escape, salvage techniques and access for fire-fighters

?? *In Scotland, Fire database holds information for Category A listed properties*

?? *Seek similar information from other member countries*

?? *If not, seek case studies to illustrate range of situations found.*

2.2 State-of-the-art solutions

1. Define range of alternative solutions and undertake risk assessments of the technologies in terms of false alarms, benefits and conservation implications

?? *Literature review of current facilities*

?? *Analyse data gathered in relation to:*

- ?? *False alarms*
- ?? *Physical impact*

?? *Test against real detection from listed building installation*

2. Consider relevance of current expertise on new and developing detection and suppression concepts, and technical techniques.
   - ?? *Identify trends in technical developments e.g. radio links, miniaturisation*
   - ?? *For each trend assess benefits/disbenefits for listed buildings*

3. Demonstrate the benefits of numerical simulation, such as Computational Fluid Dynamics.
   - ?? *Smoke behaviour modelling*

4. Identify an appropriate range of passive and active technical equipment counter-measures
   - ?? *Follow on activity from 2.2.1*

5. Consider how to minimise the aesthetic and physical impact of the installation of new fire protection technology on historic fabric
   - ?? *Case studies to be sought from member countries*
   - ?? *Manufacturers information may hold useful data*

6. Consider the prevention of fire growth and smoke spread
   - ?? *Following on activity from all preceding action points*

7. Consider design issues associated with the extinguishment of fire and smoke release

WORKING GROUP 3: CULTURAL AND FINANCIAL VALUE

3.1 Financial data and risk

1. Insurance companies have insufficient data to calculate the extent of the real heritage that is at risk. Work with insurance companies to compile statistical data on the annual cost of fire losses to historic buildings, using this information to effect understanding and change.
   - ?? *Identify relevant body responsible for insurance of buildings*
   - ?? *Insurance body Questionnaire*

2. Given the total loss of authentic fabric as a result of fire, consider principles of deciding what should be built in its place – a recreation of what was there before, or a modern replacement.
   - ?? *Case studies of examples recreation vs. modern replacement*
   - ?? *Consider types of authenticity*
   - ?? *Gather press cuttings in relation to current debates on recreation vs. modern replacement for sites destroyed by fire*

3. Re-state the importance of historic and cultural "authenticity" and significance, in particular the importance that historic buildings may have for the community and society.
   - ?? *Literature review of international research charters including any relevant charters from member countries*
   - ?? *Gathering information from each to compile composite document*

4. Determine how size, value of property, and content impacts on risks.
   - ?? *Draw on available data to assess level of risk for properties of different size, value and content*

5. Compile relevant statistics to assess correlation between early detection, response time and degree of loss.

?? *Assess feasibility of using gathered data*

?? *Identify case studies which illustrate relationship between early detection, response time and degree of loss*

6. Promote findings and benefits of relevant assessment methodologies and risk assessment gains.

?? *Assess feasibility of using gathered data to indicate effectiveness of risk assessment to reduce impact of fire.*

?? *Use of case studies*

7. Promote awareness of the real financial and cultural costs of fire loss to private historic building owners

?? *Identify bodies in each member country that can reach private owners of listed buildings*

?? *Press releases*

?? *Written and published articles*

?? *Conference and seminars*

3.2 Loss recovery

1. Accumulate, interpret and disseminate the analysis and conclusions of fire loss events, using case study examples, and including their impact on historic authenticity.

?? *Assess impact of all types of authenticity*

2. Consider alternative approaches to assist in stemming loss levels, or where these continue to occur, what other approaches may be considered as appropriate.

- ?? *Gather best practice in management techniques for reducing fire loss*
- ?? *Consider the unthinkable… e.g. disallowing access to certain listed buildings to protect from fire*

3. Reconsider approach to first-loss insurance, identifying real value and building costs.
   - ?? *Gather guidance on insurance for historic buildings from member countries*
   - ?? *Establish current best practice*
   - ?? *Include question in survey of insurance bodies regarding appropriateness of current insurance types and levels for historic properties*

4. Consider if future insurance premiums might be established on the basis of sound statistical data, of "retention" needs, "replacement" requirements, or new work.
   - ?? *Feasibility study into likely improvements in data gathering on costs of fire losses as a basis for setting insurance premiums*
   - ?? *Include question in survey of insurance bodies*

WORKING GROUP 4: PROPERTY MANAGEMENT STRATEGIES

4.1 Support for property managers

1. Devise appropriate management regimes, learning from others in Europe, through studying best practice in policy, regulations, planning, organisation, checklists, training, monitoring, hot work permission etc.
   - ?? *Gather information from member countries of current best practice*
   - ?? *Fire Questionnaire results*
   - ?? *Compile clear and easy to use best practice document for property managers*

2. As support for property managers, provide models for risk analysis of a building, training of the staff, handling of contents in case of fire.
   - ?? *Liaise with bodies responsible for moveable heritage in each member country*
   - ?? *Compile clear and easy to use best practice document for property managers*

3. Establish a balance between technical and management contributions to combat the effects of fire
   - ?? *In conjunction with WG 2.*

4. Consider the management measures that will contribute to the prevention of fire ignition
   - ?? *Gather best practice information from member countries*
   - ?? *Compile clear and easy to use best practice document for property managers*

5. Consider how the complexity of the building may initially dictate search and rescue, and then fire fighting
   - ?? *Gather best practice information from member countries, including Fire Database in Scotland*
   - ?? *Compile clear and easy to use best practice document for property managers*

4.2 Staff training

1. Offer guidance on handling of contents in the event of fire
   - ?? *Gather best practice from member countries*
   - ?? *Compile clear and easy to use best practice document suitable for use by volunteers and other staff*

2. Suggest organisational arrangements to assist in the implementation of staff training regimes

?? *Gather best practice from member countries*

?? *Compile clear and easy to use best practice document suitable for use by volunteers and other staff*

CONCLUSION

It is anticipated that the COST C17 programme progress will be monitored by means of brief annual reports from each participating partner country. These will describe the results of research obtained through concerted action. An intermediate report after 2 years of joint activity will be presented to the COST Technical Committee for their review and to the COST Senior Officials Committee for information. A final report will be prepared at the end of the Action to inform non-participants about the results. It is anticipated that Action participants will also present reviews and progress reports for publication in International Journals, and that related papers will be presented at appropriate conferences, during the duration of the programme. To conclude the Action a Symposium will be held to review the final results.

A variety of end users and beneficiaries can be identified. These include historic building owners, public asset managers, official bodies, fire brigades and fire authorities, fire industry equipment manufacturers and suppliers, professional and technical bodies, building and artefact conservation interests, Insurance companies, heritage bodies and organisations, and the tourist industry. The beneficiaries will also include the various individual historic buildings themselves, the national physical identities that aggregate into the European patrimony, and the international cultural heritage at large.

FIRE PERFORMANCE OF ARCHAIC MATERIALS

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Summary

- ✍ The term archaic material is Greek-American orientated and means a construction or a material of an earlier time, generally prior to 1950.
- ✍ The fire performance of these elements in relation to the modern fire and building Codes requirements is examined, since there is not always an easy way to determine the fire related properties of those elements.

1. Introduction

- Fire Codes and Regulations usually refer to the design of modern buildings and their primary objectives are life safety and property protection
- Historic buildings are existing structures and require wider priorities than modern buildings such as:
- Contents protection, with emphasis to those with artistic and cultural value
- Protection of the fabric, consisting of the old and/or the restored construction
- Prevention of conflagrations, in the case of larger area

Introduction (cont.)

- The rate of growth of a fire in an enclosure depends upon the following factors:
- Contents (ignitability, smoke production, distribution, rate of heat release)
- Linings (surface spread of flame,absorptivity)
- Compartment (size, shape, fire resistance, ventilation conditions)
- Interaction between contents, linings and room boundaries.
- Documentation of archaic materials fire performance is not readily available. The application of engineering judgment is rather difficult because building designers and officials may not always familiar with the materials fire properties

2. FIRE PERFORMANCE MEASURES

Fire resistance

- The standard fire resistance tests
- "Non-standard" small-scale tests
- Tabulated data
- Analytical methods

"*Ten Rules of Fire Endurance Ratings*"

T.Z. Harmathy (Canada) May, 1965

“Ten Rules of Fire Endurance Ratings”

***Rule 1:** The “thermal fire endurance of a construction consisting of a number of parallel layers is greater than the sum of the “thermal” fire endurance characteristic of the individual layers when exposed separately to fire.*

***Rule 2:** The fire endurance of a construction does not decrease with the addition of further layers.*

***Rule 3:** The fire endurance of constructions containing continuous air gaps or cavities is greater than the fire endurance of similar constructions of the same weight, but not containing air gaps or cavities.*

- ***Penetrations in Fire Resistant Assemblies***
- ***Fire doors***

There are too many unknown variables which could affect the fire performance of the door.

It is often possible to upgrade the fire performnce of an existing door.

Gypsum wallboard

Intumescent paints

DEVELOPMENT AND PROPAGATION OF FIRE

- Development and propagation of a fire in a comparment covers the period between the initial ignition until a broadly constant rate of burning occurs.
- In general, building Authorities are concerned with surface materials, mainly those lining internal spaces (e.g. rooms, escape routes) but also including external surfaces (facades,roofs).

Existing test methods

The need for harmonized test methods to reduce barriers to trade.

The development of the second generation test methods

A. Linings

Ignitability test BS 476: Part 12

Spread of flame BS 476: Part 7

Fire propagation BS 476: Part 6

B. Furniture

Ignitability BS 5852: Part 1,2

C. Furnishings

Flammability BS 5438

Ignitability BS 4790

Smoke and toxicity

European reaction to fire standard tests

The fire classification of construction products and building elements

The classes for construction products are 7 (A1, A2, B, C, D, E, and F)

Non-combustibility test	(prEN ISO 1182:2000)
Gross calorific potential	(prEN ISO 1716:1998)
Single burning item test	(prEN13823:2000)
Ignitability test	(prEN ISO 11925-2:1998)
Burning behaviour of floorings	(prEN ISO 9239-1:1998)

PROTECTING THE PAST: A PERFORMANCE BASED APPROACH

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ABSTRACT

Early in 1998 the Colonial Williamsburg Foundation' hotel company, which operates four hotels with a total of 1100 rooms, began planning the renovation of its flagship hotel property, the Williamsburg Inn. To oversee the planning and implementation of the renovation, a team of professionals, including hotel management, an architect, an architectural historian, conservation professionals, and engineers—including mechanical, electrical, structural and fire protection—began to meet with representatives of the renovation contractor and City of Williamsburg code officials to discuss the project. After careful analysis of the building against the existing building code, the renovation design team concluded that a strict prescriptive code approach to the project would not accomplish Colonial Williamsburg's preservation objectives, and a modified performance base approach was selected to address those issues where strict compliance with the prescriptive code would dictate unacceptable changes to critical elements and features of the building. This presentation examines the advantages of such an approach in solving frequently encountered fire protection problems when renovating an historic building.

INTRODUCTION

Early in 1998 the Colonial Williamsburg Foundation' hotel company, which operates four hotels with a total of 1100 rooms, began planning the renovation of its flagship hotel property, the Williamsburg Inn. The Williamsburg Inn is a luxury resort property in the Regency Style that opened in 1936 with 68 rooms. Additions in 1950, 1954, and 1972 brought the number of rooms to 100, with associated public, meeting, and dining spaces. The building is two stories with one three-story section over the lobby, the oldest part of the building.

In addition to the Williamsburg Inn's status as a luxury resort—the Williamsburg Inn held Mobile 5 Star status for over 20 years—the hotel holds a place of special importance for Colonial Williamsburg because of the personal involvement of John D. Rockefeller, Jr. in its design, construction, decoration and furnishing. In addition, in 1998 the Williamsburg Inn was added to the United States National Register of Historic Buildings. Finally, the Williamsburg Inn has a large following of devoted patrons, many of whom have visited the hotel, staying in the same room, every year for 25 years or more. Moreover, many repeat visitors consider the hotel their own special place and strenuously object to even the slightest changes. The combination of close association with the man who funded the restoration of the 18th Century capital of the colony of Virginia, the building's historic building status, and a large cadre of devoted patrons, demanded that any changes to the Williamsburg Inn be carefully planned and executed. It quickly became evident that the project objectives had to include both updating the infrastructure of the hotel and preservation of its design characteristics.

To oversee the planning and implementation of the renovation, a team of professionals, including hotel management, an architect, an architectural historian, conservation professionals, and engineers—including mechanical, electrical, structural and fire protection—began to meet with representatives of the renovation contractor and City of Williamsburg code officials to discuss the project. After careful analysis of the building against the existing building code, the renovation design team concluded that a strict prescriptive code approach to the project would not accomplish Colonial Williamsburg's preservation objectives, and a modified performance base approach was selected to address those issues where strict compliance with the prescriptive code would dictate unacceptable changes to critical elements and features of the building.

WHAT IS A PERFORMANCE BASED APPROACH?

Prescriptive based solutions are a cookbook approach to building design and fire safety; i.e., the code tells the designer what to do and how to do it. Prescriptive solutions assume that perfect compliance equals a safe building and demand rigid adherence to design requirements that may not take into account operating conditions, staffing, or new technologies. Performance based solutions assume fire safety objectives can be different, depending on the building and use, and that there is more than one way to accomplish the objectives, and engineered solutions are used to achieve specific performance based design objectives.

Performance based approaches are not new; indeed, nearly all prescriptive codes include language allowing performance based options such as equivalencies or code modifications, provided the authority having jurisdiction agrees the alternatives provide equivalent levels of protection. The Uniform Statewide Building Code in Virginia (1996 edition of the BOCA Building Code) provides all these options, as well as the ability under Chapter 34 to evaluate the overall contribution of existing building features to offset newer code requirements. The Williamsburg Inn renovation project moved beyond the normal application of these options in that the project team used a process method, similar to that found in the 2001 edition of NFPA 914, *Code for Fire Protection of Historic Structures*, to work through the myriad of design and construction details as they arose during both the planning and construction phases of the renovation. (See Figure 1.) As anyone who has renovated an old building that has undergone multiple additions knows, it is impossible to determine with any degree of certainty the problems that will surface after work starts. The key to keeping the project on track without sacrificing the preservation objectives and without undue cost is to have a process that gets all the stakeholders involved in finding acceptable solutions to problems as they are uncovered.

WILLIAMSBURG INN RENOVATION

Colonial Williamsburg Foundation's objectives for the renovation included the following:

- ?? Revitalize the ailing physical plant
- ?? Install modern fire protection systems
- ?? Bring rooms to current Mobile 5-Star Standards
  - i. Room Size
  - ii. Computer Connectivity
  - iii. HVAC
  - iv. Bathrooms and Plumbing
  - v. Electrical
- ?? Bring into compliance with Building Code to the extent possible
- ?? Maintain the historic character of the building
- ?? Keep half the building open and operating through out the renovation

The scope of work developed from the objectives included:

- ?? Architectural
  - i. Reduce the number of rooms from 100 to 68
  - ii. Restore the lobby to its original configuration
  - iii. Reconfigure service wing to add a Bar and make more executive meeting space
  - iv. Reconfigure back-of-the house space to provide more usable storage space
  - v. Relocate maintenance operations out of the basement of the building
- ?? New mechanical, electrical and plumbing systems
- ?? Asbestos & Lead Abatement

- New smoke detection & sprinkler systems
- Handicapped Accessibility Upgrades
- New exterior exit stair on the west end of the building

Finally, a thorough code review identified the following issues:

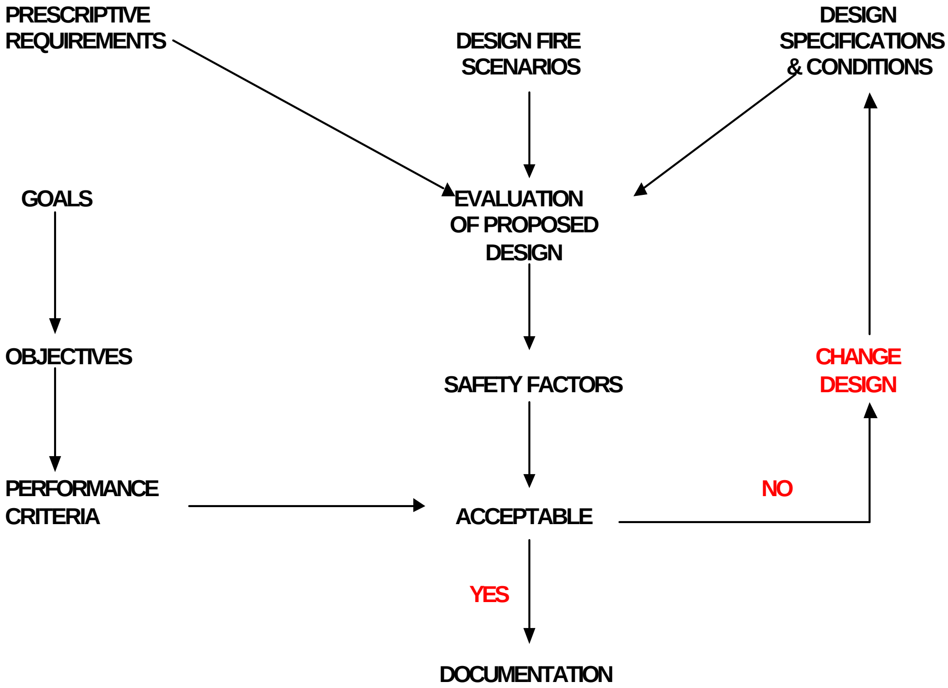
- Unenclosed architecturally significant stairways
- Room doors ½" too narrow to meet the requirements of the Americans with Disabilities Act requirements
- A dead end corridor on the second floor that necessitated adding an additional means of egress and a new exterior exit stair
- Elevation changes between the original part of the building and the additions

THE PROCESS

The design team mentioned above, working from the articulated objectives, evaluated the various alternatives to each of the design and code issues. The final plan was a combination of prescriptive code requirements, exemptions allowed for existing conditions, equivalencies, modifications, areas where existing code requirements were exceeded to offset other deficiencies, and performance alternatives. From the beginning, the team worked with the building official to negotiate and document the solutions well before drawings and plans were submitted for review. This process was important because it not only kept the stakeholders apprised of what needed to be done, it also allowed each to have a say in what was done and in the end everyone involved understood why particular solutions were implemented. Moreover, as work progressed and new problems arose, a process was already in place to identify and assess the impact of the new conditions and to cooperatively select the most effective and efficient way to resolve the issue without sacrificing any of the project objectives.

Admittedly, there were bumps along the road as the process team struggled to achieve the objectives of the renovation while staying within budget and reopening the hotel on schedule. Indeed, in the end both the plan to keep part of the building open throughout the renovation and the final opening schedule proved too challenging. About half way through the project the hotel closed down to facilitate asbestos abatement, and the reopening schedule slipped nearly six months, mostly because there was more asbestos than expected. Nevertheless, given the complexity of the project and the unanticipated structural conditions uncovered during the course of the work, the project would have been significantly more challenging without the active participation of all the stakeholders and a defined process for resolving code issues as they arose. The team came away from the project with a full appreciation of the value of a cooperative design and implementation approach and a commitment to use the same conceptual process for all future renovation projects.

FIGURE 1
PERFORMANCE BASED APPROACH



INTEGRATED SAFETY MEASURES FOR NATIONAL HERITAGE

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ABSTRACT

Problem of museum safety means examining the relationship between a museum and its territory, taking into account the total environment in which the museum is situated.
Decree of Oct. 29, 1999 "Consolidation Act of regulations concerning environmental and cultural heritage, according to Law n° 352, dated Oct. 8, 1997", characterises the issue of safety and security in the field of cultural assets, conditioning in a significant way the relative safety strategies. The introduction of a new methodology (risk analysis) utilised to date exclusively in the industrial sector. Its implementation in the field of cultural heritage protection implies a cultural change more than a professional and technical one. The method of risk analysis, for which these forms are used as a guideline in the field of cultural heritage, is an innovative approach and -as such- only its extensive implementation will provide material to assess its efficacy.

keyword
security integrating heritage

* * *

When dealing with the problem of museum safety it is necessary to examine the relationship between a museum and its territory, taking into account the total environment in which the museum is situated.

This aspect, together with the objectives of works-of-art preservation, enhancement and enjoyment by the public provided by Decree of Oct. 29, 1999 "Consolidation Act of regulations concerning environmental and cultural heritage, according to Law n° 352, dated Oct. 8, 1997", characterise the issue of safety and security in the field of cultural assets, conditioning in a significant way the relative safety strategies.

These assumptions represent the basis of Area V: "Museum safety" in the Ministerial Decree dated May 10, 2001 "Guidelines on technical and scientific criteria and on operation and development standards of museums" (art. 150, par. 6, dl. N. 112/1998). This Decree provides criteria and methods based on risk analysis for developing suitable and effective safety projects for museums.

Thus we witness the introduction of a new methodology (risk analysis) utilised to date exclusively in the industrial sector. Its implementation in the field of cultural heritage protection implies a cultural change more than a professional and technical one.

Under the Guidelines the goals of a safety system are the following:

- mitigation of effects;
- protection, preservation and strengthening of "containers";
- safeguard and preservation of "contents";
- safety of occupants and rescuers;

and the essential requirements are:

- environmental safety;
- structural safety;
- safety of use;
- fire safety;
- crime prevention.

ESSENTIAL REQUIREMENTS

The necessary requirements are often related with each other: it is up to the technician to discover, evaluate and settle the possible conflicting points among competing needs.

As stated at the beginning of this paper, one has first to analyse the territory within which the museum is located. It is necessary to assess all circumstances which may impact upon it and take all required safety measures (*environmental safety)* .

Secondly, the museum, the "container", is examined. It is necessary to evaluate whether it can support the stresses which both the external environment and internal loads exerted upon it *(structural safety)*. But the "container" must be evaluated also from the perspective of safety of use, i.e. all the problems connected with the enjoyment by the public, all the more evident especially when a structure is used in a way which differs from its original purpose. This happens, for example, when an historic building -part of a nation's heritage- becomes a museum; according to provisions of law it should be preserved unchanged but being a museum it requires emergency exits and stairs, sprinkler installations, etc:

Thirdly, museums must be protected against fire and criminal acts. While environmental and structural safety are evaluated and planned once during the museum's lifetime, fire safety and museum security are closely connected with safety of use and require strategies and procedures to be implemented every day, not only to minimise the risk of fire and criminal acts, but also to manage emergency situations when measures provided prove to be insufficient.

RISK ANALYSIS

The essential steps to be followed during a risk analysis are reported in the flow-chart below:

RISK ANALYSIS
(fundamentals of safety project)

Risk assessment ? Risks {natural / technological / anthropic}
?
Risk magnitude
? vulnerability exposition

3° level -------------
| ?
| Risk compensation ? prevention measures
| passive protection
| ? organisational measures
|
| Quantification and definition of residual risk ? definition of scenarios
| assessment of consequences
| ?
2° level -------------
| ?
|
| Mitigation of residual risk ? integrated systems (technology-operator) active protection
| ? operational procedures
1° level -------------
| ?
|
| Management of residual risk ? emergency planning
| ? emergency management
|
| Compatibility check ? drills
| ? simulation with models
|________________________________OK

Facing the problem of safety through risk analysis implies -first of all- the assessment of the risk itself, being aware that it can be minimised up to a certain level, compatible with its management, although it may never be completely removed.

Once the risk is assessed, one has to adopt suitable compensation measures, such as passive protection systems which reduce both exposition and vulnerability factors. However, compensation is generally unable to render the residual risk acceptable; thus it is necessary to mitigate residual risk through the use of active protective systems represented by the integration of installed systems and their operation by trained and efficient operators.

Once the risk has been mitigated, one has to evaluate whether the residual part can be managed with the economic and human resources available in the museum.

It is worth noting that the process which leads to safety strategies cannot be the same for all museums, but it must be developed and adjusted case by case to avoid the possibility of adopting less effective measures.

Considering the irreplaceability of cultural heritage, the minimisation of risk becomes a moral duty which has to put aside all economic considerations. Therefore, the compatibility check must be founded on the awareness of having adopted all possible protection measures.

In particular, this integration is essential in three different stages: the development of organisational measures, the planning and management of active protection systems, the planning and management of emergencies. This allows operators to resolve possible competing and sometimes conflicting needs. Let's think of the emergency exits, unavoidable from the point of view of safety, but a vulnerable point in terms of security; or the introduction of additional services (cafeteria, book shop, nursery, etc.) to fully enjoy a museum, which in turn give rise to remarkable safety problems; or even the "armouring" of some 'sensitive' rooms (such as control centres) which may conflict with the operators' working conditions.

SURVEY CARDS

Service VII: 'Cultural heritage protection' has prepared a series of forms to gather necessary information to support planners in the development of a safety project by means of the risk analysis.

Such forms take into account the structure of cultural assets and gather data in a comprehensive and organic way to evaluate, compensate and mitigate the risk. With regard to technical installations they refer to current technical rules and standards. In fact they have been developed in co-operation with CEI and UNI, the two main Italian regulatory authorities.

Cards are divided into four groups:

- general cards
- cards concerning fire safety
- cards concerning security
- cards concerning technological installations and facilities

Each group contains some forms regarding the museum in general and others are more concerned with details. It is worth noting that a museum can develop over a wide area, containing more than one building, having rooms and spaces with different occupancy: from exhibition rooms, to laboratories, carpenter workshops, storage rooms, book shops, offices. Therefore it is indispensable to collect information concerning all activities and their possible interactions.

Cards concerning general aspects are used to collect data on the total environmental context, so as to gain a global overview of the site, of its territory and relative risks, exposition and vulnerability factors.

Then the lay out of the site is examined and the relative form collects information on the use of outdoor areas (squares, parking lots, gardens, etc.), the number of buildings and their interconnections, possible temporary structures, indoor facilities, etc.

By proceeding with the analysis, the data becomes more and more detailed and relates to any room and occupancy of the building (exhibition rooms, archives, libraries, storage rooms, …) and for any of them there are ad hoc forms.

The last forms of this group concern:

- the state of the installations from an administrative point of view (certification, approval, test, revision)
- the organisation of personnel as to safety management as well as training and information.

The second group of cards, concerning fire safety, considers first the territory surrounding the museum: proximity of fire stations, presence of water hydrants, accessibility for rescue vehicles, and so on.

The more detailed forms collect information on the presence of "compartments", or on fire loads, ventilation characteristics, fire door resistance. Some forms deal with technical facilities: detection systems, extinguishers, hoses, sprinkler installations. The last two forms take into consideration the features of emergency routes and control centre.

In the third group of forms concerning "crime prevention" the stress is on organisational and managerial aspects (surveillance, visitors' flux), management of keys (and relative access procedures, responsibility and availability of people in charge).

Other forms verify the compliance with technical standards, specifically CEI 79 regulations, concerning protection against intrusion and trespassing. The goal of these cards is to collect data necessary to establish the "*performance level of security systems*". The result is a digit from 1 to 3 representing an indicator of the installation quality. This indicator is obtained starting from the performance level of each component and applying specific calculation models provided for in technical regulations. An installation with a performance level equal to 0 cannot be classified and therefore cannot be considered as in compliance with CEI regulations.

Also protection against criminal acts requires -as fire safety- the identification of rooms to be protected by safety installations. However, while in fire safety the different rooms are "compartments" or physically well defined zones, independent from each other, in case of crime prevention, it is necessary to identify two concentric areas for each room, external to it: the building containing it and the area outside it. The latter is identified by a fence and a free space between it and the building. Therefore, "security" cards concern the following aspects:

- external area,
- building
- protected room, which can be one or more exhibition rooms, a storage room, a vault, a strong-box, etc.

Each of these forms is aimed at collecting data concerning lay out, typology and performance level of detectors to control entrances (trespassing protection), surfaces (intrusion protection) and volumes (protection against intruders in the controlled volume) .

From these data it is possible to calculate the performance level L_A of this part of the installation. Other two forms deal with *alarm systems*, *operators' room* and *other possible optional bodies*.

The fourth group of forms is connected with the technological systems present in the museum: electric system, heating and air conditioning, elevators, goods lift, natural gas distribution system, escalators. For each of these installations there is a card for collecting performance and technical data.

The method of risk analysis, for which these forms are used as a guideline in the field of cultural heritage, is an innovative approach and -as such- only its extensive implementation will provide material to assess its efficacy.

DESTRUCTION OF OUR HERITAGE – AVOCATION FOR A RISK MANAGEMENT APPROACH

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ABSTRACT:

Our cultural heritage is being eroded by Natural Catastrophes and Fire; hazards which are well known and preventable. Industry in Europe took a Risk management approach to mitigate similar risks with a considerable degree of success and the question is posed as to whether Heritage sites could learn through the Highly Protected Risk (HPR) concept.

Risk Management looks to three basic principles: Risk Avoidance (Prevention), Risk Reduction (Protection) and Risk Financing (Insurance) and how these could apply to Heritage sites are explored. It is argued that "Insurance" is not a good strategy and while "Prevention" tools are vital they are not enough. As "Protection" is critical for industry to be HPR so too should it be for important cultural sites. Contingency planning and automatic protection are the backbone of the protection principle.

Key Words:

Prev[1]ention, Protection, Insurance.

[1] ? **Brief Career:** Loss Prevention engineer in Industrial Risks for 25 years, 3 in UK, 3 in USA, 15 in Italy and 4 in France following major Industrial clients (reference: Fiat, Georg Fischer, ST Microelectronics, EuroDisney, Agfa Gevaert). Currently responsible for all Technical Loss Prevention Standards and Engineering done by FM Global in France Benelux and Iberia.

..*

Each year fire and natural hazards devastate our cultural heritage. Fires ravage historic theatres, churches and monuments of historic significance, floods invade basements, ruining archives and earthquakes shake old and infirm cathedrals and castles. The deepest irony of the erosion of our heritage is that most of it can be prevented!

Faced with a not dissimilar dilemma two decades ago, many major European Industrial Corporations responded by introducing "Risk Management" as a core activity to protect themselves from the uncertainty of Risk, one aspect of which was the physical risk to their plants and the business interruption from damage caused to them. The concept of the "Highly Protected Risk" (HPR) was widely adopted and some 20 years on, the benefits of such a tactic are agreed by senior Corporate Management.

Could Heritage Sites benefit from such an approach and learn from the Industrial sector?

Looking more in detail at the way Industry applies Risk management one sees three basic principles:

- Risk Avoidance (or Prevention)
- Risk Reduction (or Protection)
- Risk Financing (or Insurance).

Let's look at these in turn and think of their suitability as a tool for Heritage Sites.

1. Risk Financing – Insurance

While ultimately having the financial backing of insurance will mitigate most of the financial pain of a physical loss for an industrial company, this may be the least relevant mechanism for heritage sites. Much of our heritage is actually the property of the State and as such self insurance is not uncommon. There is also the problem of finding the correct level of insurance at an affordable price. Insurance of items such as “fine arts” is a much specialised affair with relatively few insurance carriers able to offer a suitable level of coverage. Finally there is the obvious problem that heritage may not be replaceable. One could argue that historic buildings can be repaired and replaced and Windsor Castle would be a prime example. How do you replace an art collection or ancient archives or books?

2. Risk Avoidance – Prevention

There is often an argument that it is difficult to prevent damage from Natural Hazard Risks, particularly if it is building infrastructure that is concerned. What can you do about a cathedral in a seismic area or a museum beside a major river? However in the industrial arena, engineering has been very successful at reducing damage due to earthquakes, hurricanes and most natural hazards. Much of it does not require major work to the infrastructure. As an example shutting off gas or water supplies automatically will prevent water damage and gas explosions following an earthquake. Simple roofing assessments with cheap fixes can stop major roof damage if not from the full force of a hurricane, certainly within a few kilometers of one.

What can clearly be done is to prevent damage to artifacts of considerable value inside buildings that may be exposed to natural hazards. Recently important archives in France were removed from the basement of the Louvre, due to the exposure should the Seine flood. One could argue that priceless masterpieces should not be kept or displayed in known flood zones. Today many are!

In an industrial environment, and one can imagine a heritage one too, basements are where slow moving goods are put. They are rarely empty. While a company’s “five year financial” archives may have little commercial value, the same cannot be said for historic archives, which literally may have incalculable value.

When it comes to "Fire" prevention is a little more obvious. To understand fire and its prevention it may be worth looking at the causes of fire. (Refer figure 1). While "electrical" is the leader in industrial fire causes, and one suspects also in heritage fires, many of these causes involve what is generally referred to as the "Human Element". Man directly causes the fire or responds in an erroneous way in 70% of all industrial fires (10 year study 1991-2000 by FMRC).

Two of the most preventable of fire causes are "Hot Work" and "Smoking". Heritage sites should relate to Hot Work in the more generic notion of "Control of Contractors". Almost by definition maintenance is continuous on old buildings; roofs have to be repaired, electrical systems become outdated and need replacing, sites need modifying with decorating and refurbishing. Are the management and the workers of contractors aware of the hazards posed in heritage sites? Are they taking correct precautions? Are they being adequately supervised? If not, disaster beckons.

Then there is the risk from Arson…..Is this truly preventable?

It is argued that damage, from fire particularly, cannot be eliminated by prevention means alone. There has to be a Risk Reduction (Protection) element within our Risk Management model and this is as true for heritage sites as it would be for industrial ones. Were we serious we should adopt the "HPR" concept for critical heritage sites.

3. Risk Reduction – Protection.

Protection should foresee both manual and automatic intervention. It is worth considering the "hazard" posed by fire to heritage sites. Hazard would be defined as "the extent of what may happen together with a common sense measure of its likelihood". Heritage sites tend to feature complex layouts with multiple rooms and floors, extensive use of wood in the construction with combinations of joists and floors creating concealed spaces. Some sites can be remote for fire fighting or not have water resources nearby. Much dependence is put on the Fire Departments to minimise damage from fire. However their primary concern is for the safety of people, public and employees, and initial focus is for the safe evacuation of them. It cannot be guaranteed that the Fire Department will keep a fire from causing extensive damage to heritage sites. They do heroic effort at saving lives but they also have their own safety to think about and a fire raging in a concealed roof space will eventually cause collapse. No wonder then that once people are accounted for most fire fighting effort is from outside a building.

Concealed combustible spaces pose one of the biggest threats to any valuable old building. Once a fire spreads into such an area it is almost impossible to control manually. If there is no automatic protection then the outcome can be total destruction as in the Arlington Race Track fire in 1985 and the fire in the Fenice theatre in Venice.

Contingency Plans can and do greatly reduce the extent of fire damage and some elements to consider in such plans could include:

?? Pre-emergency planning

?? Back-up plans

?? Joint exercises with Emergency Services

?? Locating alternative sites

?? Access to emergency equipment both on-site and off-site

?? Actions during and immediately after an emergency (salvage)

However, with the best insurance, the best prevention techniques and excellent contingency plans, without automatic protection all could be for naught. To get to an "HPR" level some degree of automatic protection needs to be considered.

There has been an historic aversion to automatic sprinkler protection as a protection means for historic buildings, just as there was in industry in Europe over twenty years ago. At best automatic sprinkler protection is “misunderstood”. It is an extremely versatile, effective form of fire protection that, together with expected action of a Fire Department, would limit direct fire and water and smoke damage to a small area. In 90% of fires where sprinklers are installed and operate control is gained from just 5 sprinklers or less. In industry the average damage from a sprinkler protected fire is one sixth that from one without protection. One hears the outcry “but they are ugly, they are difficult to install, they are expensive, they will not work”. However, against this one could argue “so, it is preferable to risk losing a room of Boticelli’s masterpieces?”

Now today there are other forms of sophisticated automatic protection systems, none of which would be as reliable as the automatic sprinkler but may have benefits of being less obtrusive.

To conclude, to stop the further destruction of our heritage we should look to a Risk management process that above all focuses on Prevention and Protection techniques. It should not only focus on fire but on natural hazards too.

Ultimately, is there a price too high to pay to keep our treasures safe for our children and grandchildren?

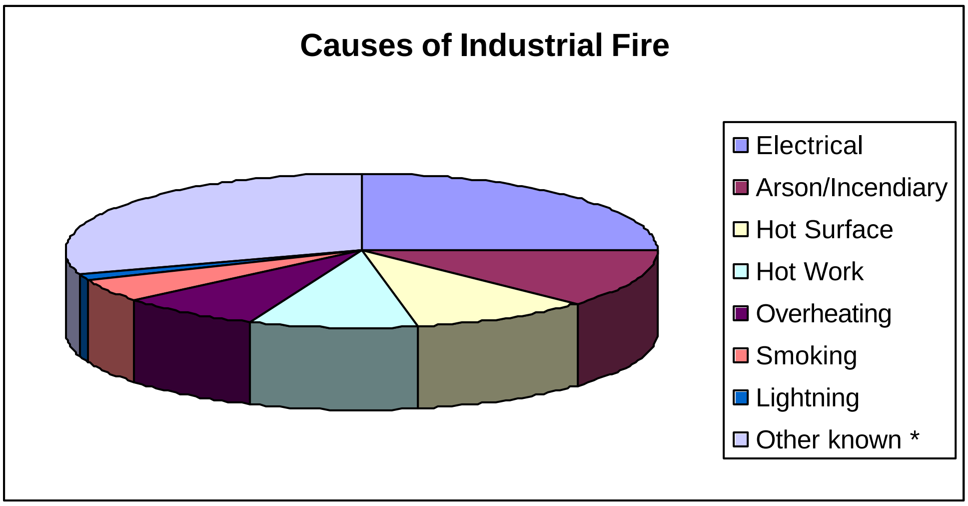

Figure 1 (source: Loss Analysis of FMRC 10 years 1989 – 1998)

ITALIAN AND EUROPEAN STANDARDS FOR ELECTRICAL INSTALLATIONS OF VALUABLE BUILDINGS HAVING HISTORICAL AND/OR ARTISTIC IMPORTANCE

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Abstract

The Italian Law 46/90 on safety of technical installations has given a strong impulse to the sector of the electrical installations in all its various aspects: design, installation, verification and maintenance for every kind of buildings (both civil and industrial).

The historical and artistic buildings too are subjected to this law, with a particular difficulty in addition: in a lot of applications it is not easy, or sometimes possible, to satisfy the requirements of the law for the existing installations, due to the fact that there is the risk to damage the goods exposed in these buildings that have an inestimable economic value.

This paper illustrates the situation of the technical standardization activities in the field of buildings having historical and/or artistic importance and that are subject to artistic ties.

We present in particular the content of the Experimental Standard CEI 64-15 with a short presentation also of another CEI Standard, identified by code CEI 83-11, that deals with installation of Bus systems.

Keywords: Artistic tie – Electrical installations – Historical buildings

INTRODUCTION

The historical buildings have two opposite needs with respect to its technical installations: to maintain an high level of quality of these installations and to preserve the buildings themselves and the goods that are exposed within them.

In many cases for these needs is not possible to combine the above mentioned different topics and therefore it is necessary to prepare particular Standards or Codes of Practice or Guides, in order to offer a tool to the owners and users of the historical buildings.

This tool shall represent the “Best practice” (in Italian Regola dell’arte) in the field of the electrical safety.

Before the presentation of the specific standards (national or european) that deal with these aspects, it is necessary to explain who is CEI (the Italian Electrotechnical Committee), its scope, its way of work.

THE ITALIAN ELECTROTECHNICAL COMMITTEE

Founded in 1909, CEI – Comitato Elettrotecnico Italiano – is the Italian institution, formally recognised by the Italian Government and by the European Union, that prepares and publishes technical standards in the electrical, electronic and telecommunication fields.

CEI’s mission is to promote and spread technical culture and electrical safety of products. In order to fulfil its mission CEI performs a number of standardization and pre-standardization activities both at national and international level. These activities include, besides the preparation of standards and the endorsement of European Union Directives and of the harmonized documents, co-ordination, research, development, communication and training in co-operation with other institutions involved in the standardization process.

CEI is a private non-profit association and it operates under Statutes that were last revised in 1999 (previously in 1992) and published in the Italian Gazette.

Three Italian laws establish the legal recognition of CEI as national standardization body:

?? Law n° 186 – 1 March 1968 “Rules about the production of materials, equipment, machines, installations and plants”. This law states that materials, machines, equipment and plants built according to the standards prepared by CEI are to be considered as responding to “best practice” (the Italian is “regola dell’arte”).

?? Law n° 791 – 18 October 1977 “Implementation of the European Directive (73/23/CEE) concerning safety of electrical material to be used within certain voltage limits”.

?? Law n° 46 – 1 March 1990 “Rules on safety of electrical installations of buildings”. Article 7 of this law states that installations are to be made according to best practice and using materials also manufactured according to best practice.

The standardization activity is carried out by the experts nominated by the members within the Technical Committees and Subcommittees that are in charge of the development of technical standards in the different sectors.

CEI’s standards establish the basic requirements which are to be embedded in electrical and electronic materials, machines, equipment, appliances, installations, plants, in order to grant that they respond to the rules of good practice. At the end of the standardization process the characteristics, features and conditions of safety, dependability, quality and testing methods are defined.

CEI is the Italian representative member in the major international standardization and certification bodies:

?? IEC (International Electrotechnical Commission)

?? CENELEC (Comité Européen de Normalisation Electrotechnique)

?? IECQ (IEC Quality Assessment System for Electronic Components)

?? IECEE (Système CEI d’essais de conformité aux normes de sécurité de l’équipment électrique)

?? CIGRE (Conférence Internationale des Grands Réseaux Électriques à Haute Tension)

?? AVERE (European Electric Road Vehicle Association)

?? ETSI (European Telecommunication Standards Institute) represented in Italy by CONCIT, National Committee for co-ordination of Information Technology and Telecommunications.

As stated by its Statute, CEI is a cultural, non-profit organization. Its main objectives are listed below:

?? to prepare, publish and spread technical standards to associate members and to those operating in the electrical and electronic field

?? to set the requirements of plants, materials, equipment, machinery, processes to make them work according to best practice

?? to set criteria for adequate safety and quality levels of products and processes; to set rules and procedures for tests and controls

?? to provide symbols and vocabulary related to standardization in the electrical and electronic field

?? to promote cultural activity and research in order to set the basis for pre-standardization activities and to keep the pace of technological development

?? to study technical and scientific issues in order to prepare technical standards and promoting their use in Italy

?? to take part in the activity of international and European Bodies in order to promote and endorse at international level the harmonization of standards and to grant the implementation of European Directives

?? to set relationships and links with the public administration, other associations and bodies involved and interested in the standardization activity

?? to promote and spread training actions in the field of technical standards, publishing guides and books and setting up courses and workshops

?? to enhance research, culture and training in the academic world on topics related to technical standardization

?? to promote and enhance certification activity

A LOOK ON STANDARDIZATION

CEI works in tight co-ordination within CENELEC, (Comité Européen de Normalisation Electrotechnique); according to the rules of standardization:

?? basic standards in Europe are the ENs or HD Publications

?? If an EN or HD is published by CENELEC, every European National Committee shall endorse it as a national standard.

Unfortunately, there is a normalization lack, at CENELEC level, regarding electrical installations of valuable buildings having historical and/or artistic importance: this is not the case in Italy because the Italian Electrotechnical Committee has prepared, in October 1998, the Standard CEI 64-15 "Electrical installations of valuable buildings having historical and/or artistic importance".

Taking into account the peculiarity of the historical buildings, this Standard is considered an Experimental Standard, that means that it has a limited validity for a specified time: after this period the standard can be maintained, as definitive standard, or reviewed or withdrawn.

Why and how this standard has been developed? What are its scope and contents? We will try to answer to these questions in the following.

CEI 64-15: AN AD HOC ITALIAN STANDARD

The Italian Law 46/90 on safety of technical installations has given a strong impulse to the sector of the electrical installations in all its various aspects: design, installation, verification and maintenance for every kind of buildings (both civil and industrial).

The historical and artistic buildings too are subjected to this law, with a particular difficulty in addition: in a lot of applications it is not easy, or sometimes possible, to satisfy the requirements of the law for the existing installations, due to the fact that there is the risk to damage the goods exposed in these buildings that have an inestimable economic value.

For this reason, with the cooperation of the experts of the Ministery of Cultural Resources, CEI has issued Standard CEI 64-15. It is necessary to draw the attention on the scope and the object of the standard: its applies to all buildings that are under the control of the "Sovrintendenza delle Belle Arti", a body of the above mentioned Ministry.

In the following Table 1 the object of this standard is illustrated.

Table 1 Scope and object of the Standard CEI 64-15

Scope **This Standard applies to electrical installations of buildings having historical or artistic importance and of buildings intended to contain, public or private, libraries, archives, museums, galleries, collections and objects of cultural interest, which are subject, according to national laws, to tutelage by a public authority.** Object **This Standard applies to new electrical installations and to existing electrical installations which are partially or completely remade, in buildings which are subject, according to national laws, to tutelage by a public authority.** **Furthermore, it is not intended to be applied to electrical installations of buildings or objects which have historical or artistic importance, but which are not subject, according to national laws, to tutelage by a public authority.**

The buildings object of the standard can be both public and private buildings, but in any case these structures shall be subject to the artistic tie: the latter is defined as a legal requirement intended to maintain the complete or partial integrity of a structural part or of objects which practically prevents or substantially limits the possibility to make electrical installations in compliance with the general rules.

The existence of an artistic tie shall be certified by a responsible Authority and shall appear in the design documentation.

The artistic tie is therefore the thread of the scope of the standard, taking into account the safety requirements fixed by the Sovrintendenza that must remain satisfied during the years for all kind of buildings.

Another aspect of the standard is the principle of "Equivalent safety modification".

With this term we intend to describe a safety measure alternative to the one required by other standards, but which is considered as having the same degree of safety and which may be used only where artistic ties not permitting the complete compliance with such standards exist.

The artistic tie has allowed to define specific terms that cannot be accepted in the general rules for ordinary buildings: these definitions are reported in Table 2.

Table 2 Definitions

Temporary electrical installation **An electrical installation intended for occasional needs of limited duration and which is removed at the end of such needs.** Permanent electrical installation **An electrical installation which is not temporary and which is intended to supply with continuity current using equipment.** Fixed electrical installation **An electrical installation which is permanently fixed to a stationary structural part or to a non removable structural parts of a building.** Non removable structural part **A structural part intended to support the electrical installation which is not fixed to the building structure, but which, for weight, dimensions or geometrical characteristics, cannot be practically removed without the use of tools or of mechanical means of transportation.** **The use of such structural parts in locations accessible to the public is only possible if the locations are surveyed.** Movable electrical installation **A permanent electrical installation which is not fixed to a stationary or to a non removable structural part.** Obstruction **A structure which is intended to keep the public far from electrical equipment.** **In surveyed locations, such obstruction may consist of ropes supported by non stationary means or by objects which belong to the furnishing, such as chairs, divans, settles, etc.**

The presence of the artistic tie allows particular solutions: for example, the use of existing wiring systems, embedded in walls or surface mounted, not complying anymore with the standards in force, is permitted but under the following conditions:

a) artistic ties shall exist not permitting to follow different runs;
b) conduits and trunking systems shall be buried in non combustible structures or, if they are surface mounted, they shall be metallic and have a suitable degree of protection against external influences, in any case not lower than IP4X;
c) conduits and trunking systems shall not be such as to cause abrasions to the insulation or breakage of the conductors during the installation of the cables. In case of doubt, it is necessary to verify the insulation resistance and the electrical continuity of the conductors.

OTHER SOLUTIONS

The CEI Standard deals with the requirements both for the protection against fire and for safety services: in this last case safety services shall ensure, in the locations intended for the presence of public, an illumination adequate to identify the exit ways, even in case of a failure of the main power supply.

In addition the service continuity shall be ensured for all circuits having purposes of tutelage of artistic properties, including those intended to prevent thefts or to avoid damages due to vandalism or to panic conditions.

All circuits intended to protect the artistic and historical properties are to be considered circuits of safety services. Circuits of safety services shall then be provided for all the following applications, when required by laws or by public authorities:

- lighting,
- anti-fire alarms,
- fire extinction installations,
- anti-vandalism alarms,

- anti-panic sound diffusion,
- TV systems for surveying purposes,
- anti-fire elevators,
- climate control having the purpose to protect the artistic properties.

Regarding protective measures against fire, The CEI Standard specifies that the circuits which are contained in the same wiring shall be protected by an overcurrent protective device also on the neutral conductor. This protective measure is not needed if the circuit is protected by means of a residual current protective device (RCD) having rated residual current not exceeding 30 mA.

All protective devices protecting circuits supplying socket-outlets shall have a rated current not exceeding that of the socket-outlets that they protect. In addition all circuits supplying socket-outlets shall be protected by means of RCDs having rated residual current not exceeding 300 mA.

A monitoring device able to detect the situation of the leakage currents of the installation shall be provided.

The above mentioned measures are only some of the requirements contained in Standard CEI 64-15 and the importance of these tools is that they permit to reach an high level of safety without damaging the structures and the goods that they contain.

The historic and artistic buildings are considered to have high risks regards the protection against lightning: in this case the buildings shall be protected against lightning in accordance with the relevant standards in force (Standard CEI 81-1) and for the purpose of evaluating the risk in accordance with the procedures in force, a building shall be classified as “Museum”, since the loss of a cultural patrimony which cannot be substituted is envisaged.

The Standard CEI 64-15 will be transmitted to CENELEC in order to be used a draft of a possible European standard so to fill the lack in the standardization work mentioned in the first part of this paper.

In conclusion of the explanation of the Experimental Standard CEI 64-15, we point out the important recognition that the Ministry of the Cultural Resources has given to this standard: in fact it is considered as the

fundamental reference in order to verify the state of the safety of the artistic tied buildings, by the compilation of the particular data sheets.
Once this operation is completed, the whole situation of the building is known, and the eventual interventions or improvements can be planned.

THE FUTURE

Standard CEI 64-15 recommends, during the design phase, to study solutions of installations that permit to have the minimum environmental impact due to the technologies used with regards of the structures and the goods, taking also into consideration all the modern available technologies such as for example: Bus systems, Infrared, Optical fibres, etc.
If we consider Bus systems, the Italian Electrotechnical Committee has issued the Standard CEI 83-11 "BUS systems for art and history valuable buildings".
These systems allow to carry out simplified installations, easily adaptable to the planimetric and structural characteristics of the historic building, without the need to have heavy and sometimes not acceptable works. Bus systems permit, furthermore, to integrate the electrical installations with alarm systems, fire alarm installations and other technical installations.
This standard presents the state of the art of bus systems and allows a complete overview of all the applications of this technology within locations and goods subject to artistic ties.

CONCLUSIONS

This paper has illustrated the situation of the Italian standardization works in the field of safety of electrical installations of valuable buildings having historical and/or artistic importance: this, taking into account the need to have correctly designed and installed electrical systems together with the ties to preserve monuments or goods of inestimable economic value.
Considering that Italy presents a huge number of such artistic buildings, permanently visited by thousands of tourists, students, families, etc., it is evident the importance of facing a challenge of this kind.

THE APPLICATION OF THE PERFORMANCE-BASED APPROACH: THE CASE-STUDY "SANTA MARIA DELLA SCALA" IN SIENA

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ABSTRACT

Fire protection of historic buildings in only a few cases is able to find adequate solutions under prescriptive rules. Very often, the problems caused by the contemporary presence of conservative and fire safety needs lead to either the alteration of the original lay out of the building or to the unsuccessful implementation of safety measures. In this case performance based techniques seem to be the only approach able to ensure both heritage safety and preservation. The NFPA 914 code, developed for the evaluation of historic structures, is an essential reference for those who want to apply the performance based approach to national heritage. Among the undoubted advantages provided by this code, technicians have to analyse its possible application to large historic structures, where people and works of art are exposed to extremely complex hazards. To this purpose we present the case study of Santa Maria della Scala in Siena, where occupancies like museums, exhibitions, restaurants, cafeteria and a shopping mall share the same structure of 35000 square metres on seven floors, three of which are under the access level for rescuers.

Keywords

Fire protection heritage

FOREWORD

The necessity of enhancing our national heritage by allowing a special use able to finance its maintenance and preservation implies in many cases the introduction of new occupancies. The activities that are politically acceptable for each historic structure may, in turn, give way to different problems with regard to the structures themselves. One main problem is the risk of fire. In many cases, especially in large structures, their proportions invite the presence of different activities, such as restaurants, conference halls, shopping malls. This option is important to give life and access to the structure and its maintenance, but it creates special problems concerning public safety as well as cultural assets preservation.

fig. 1 - middle age drawing of the hospital

THE MONUMENTAL STRUCTURE OF SANTA MARIA DELLA SCALA

The structure is opposite the Cathedral in Siena and it was one of the first hospitals in Europe. It was built to accommodate foundlings, the poor as well as pilgrims walking along the via Francigena. That route connected Rome with countries beyond the Alps, and for centuries it has been one of the most travelled routes in the world.

The original core of the structure is a church, which was built around the mid XIII century and got its actual shape at the end of the XV century. At the end of the XIII century the "Spedale" (hospital) included the city walls which run along its properties downhill and also a road, still evident today inside the structure. Most great artists of Siena worked in the hospital, which can be considered now the third artistic centre in the city, after the Cathedral and the Palazzo Pubblico.

The restoration works of Santa Maria della Scala were launched in July 1998. In 1992 the Town Council of Siena promoted an international contest for the restoration of the "Spedale" after the decision to transfer all clinic activities still carried on in the building. The goal was to restore the historic structure and to transform it into an integrated museum complex containing the Art Gallery, the Archaeological Museum, temporary exhibitions, a Documentation Centre for Restoration Works and other services (cafeteria, restaurant, self-service restaurant).

fig. 2 . location of the complex

Since 1998 Santa Maria della Scala can be considered as a building site-museum complex, where visitors and tourists witness the progress of restoration works. Restoration activities are still in progress with the same enthusiasm and determination of 1998 according to the following:

- a decision to carry out works in different areas and intervention modes, keeping open the Museum, to enable the city and the public to enjoy the building during the long restorations;
- planning of guided tours to the construction site, to show the meaning and the features of works to the public;
- organisation of 'teaching sites', to ensure the training of special operators (archaeologists, restorers, decorators).

Even the peculiarity of the economic intervention make this case a "pilot project": the Town Council finances restoration works through the public offering of Municipal BOC ("stocks" purchased by the citizens).

The intervention was developed in three phases:

1° phase - (1998-1999) removal of all modern additions (XX century) built to improve the use of the structure as a clinic.

2° phase-(1999-2000) 'light' restorations to use the old barn and warehouses (Granaio and Magazzini della Corticella) for temporary exhibitions

3° phase -(2000-up to date) Comprehensive restoration of homogeneous areas, aimed at the complete recovery of the structure (from an architectural, technological and functional point of view)

During the last phase the Archaelogical Museum was placed in the basement of the structure, the so called "cunicoli" (tunnels). They are particularly attractive rooms, partly excavated in "tufo" stone, partly constructed in brick, which represent the foundations of the Spedale and extend up to Piazza Duomo. During the centuries these underground rooms had been used as storage facilities, technical spaces, warehouses.

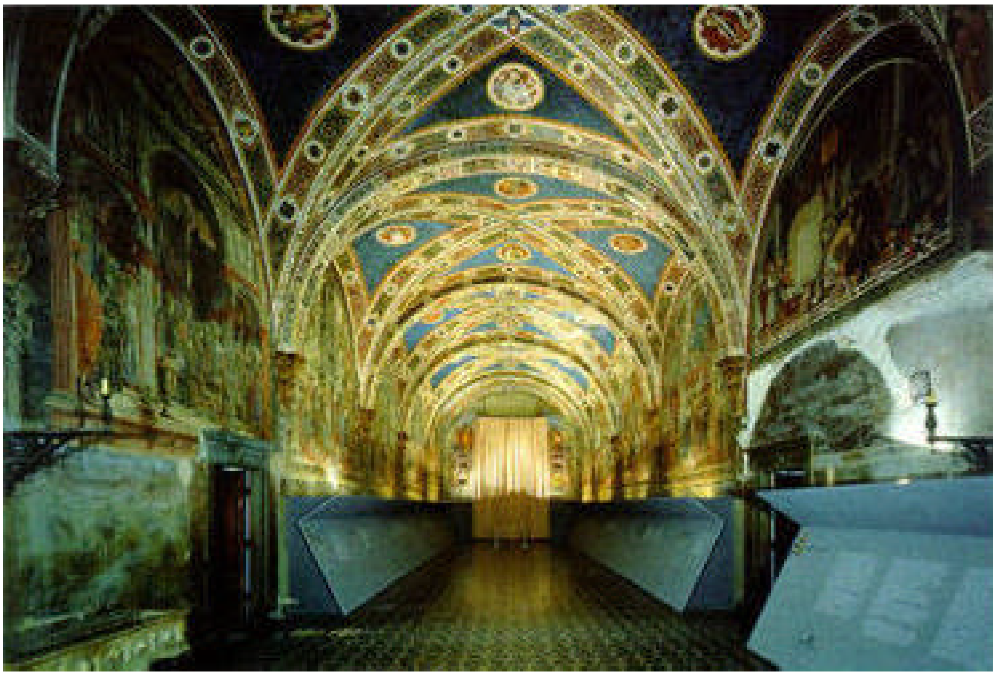

fig. 3 The “Pellegrinaio” (pilgrims) room

Before the restoration they presented several floor level differences, were filled with materials and recent technical constructions, some rooms were not accessible or not communicating, some were filled with "tufo" stone. A large area -which has been preserved- was characterised by the presence of the "carnaio" (carnage), a depot of human bones dating back to the plague which struck Siena in the XVII century.

The characteristics of these tunnels seemed to fit particularly well with the exhibition of archaeological finds, intensifying their sacred and ritual features, beyond a simple taxonomy.

The Archaeological Museum, the Granaio and the Magazzini della Corticella are now open to the public.

PERFORMANCE BASED APPROACH AND NFPA 914 CODE

This new approach requires the definition of fire scenarios, the identification of performance criteria and the verification of performances themselves. When applying this approach to historic buildings it is necessary to take into account the following elements:

- knowledge of material behaviour, which usually differs from the behaviour of modern materials (no availability of accurate data concerning fire resistance);
- identification of fire scenarios, i.e. of the conditions which might be significant to evaluate fire spread.

The identification of fire scenarios is an essential element in the process of performance assessment, because in this phase technicians have to define the characteristics of the activity with regard to the risk of fire. In case of historic monuments the problem of the identification of scenarios is more complex because it is necessary to evaluate the effects of fire on particularly exposed and valuable property.

In order to solve this problem technicians have to refer to current regulations. In particular in Italy and Europe no one has developed a code concerning the application of performance based criteria. General guidelines have been provided by ISO with the document "Technical Report 13387" and in the United Kingdom by British Standard DD 240. However, the reference for application criteria is the NFPA 101 code and the NFPA 914 (historic structures). Both NFPA codes envisage the assessment of eight fire scenarios. NFPA 914 adds four more scenarios with the aim of assessing works of art or buildings to be protected.

Fig. 4 the inner road

On the basis of the gained knowledge of the monumental complex of Santa Maria della Scala in Siena, some elements will be presented which - according to the authors - make it advisable to carry out an in-depth assessment:

a) Emergency routes and architectural barriers

Historic structures are rarely accessible and, in many cases, the removal of architectural barriers can be a difficult problem to solve for those who have to evaluate escape possibilities and speed for both able and disabled people.

b) Construction sites for building or restoration works

Historic structures are, by their nature, subject to frequent ordinary and extraordinary maintenance works. Moreover, restoration sites can be active for years and their presence can heavily affect the parts open to the public. Historic investigation has revealed that renovation works are the most frequent source of fire in historic buildings.

c) Temporary installations and exhibitions

Usually the public is admitted in the most significant areas, where smoke damages are not allowed. In such areas exhibition cases are set up with built-in electrical systems, or other devices installed after the necessary fire prevention approvals, because they are not considered significant for safety purposes. Also in case of temporary exhibitions there is the risk of frequent changes in the exhibition lay out with the consequent impossibility to determine the effects of each scenario on the historic structure. In this framework the management of electrical systems and devices is of paramount importance. Even if the use of such devices is ruled by specific standards, the authors would like to highlight some particular aspects:

- light fittings installed on tracks with clamps, which may fall onto combustible materials;
- floor lamps (while moving them to clean the floor it is possible to touch curtains or other materials);

- TV sets, screens, projectors, loudspeakers, etc. which sometimes are installed in walls or cases reducing their cooling possibilities (they may be equipped with cooling fans or vents for heat exchange)
- TV sets, screens, projectors, loudspeakers, etc. left in stand-by mode even when they are not used;
- alterations of electric systems and plugs, use of extensions;
- overheating of multiplugs due to joule effect of electric system wires. They are subject to cracks and "loosening" which cause local temperature increases;
- extensions which can be placed in passageways and be subject to wear and tear due to trolleys, closing doors, etc.. Sometimes they are fixed on walls with unsuitable systems (e.g. nailed) and become de facto an unauthorised change of the fixed system;
- everything which is not included in the fixed electric systems (which are built-in in walls) and may be subject to additions, changes, etc.

CONCLUSIONS

The NFPA 914 code allows technicians to carry out risk assessments according to the performance based approach in historic structures. In case of particularly complex buildings such an assessment must take into account not only the problem of accessibility, but also management issues. In fact, the possible differences between the real situation and the situation assumed in fire scenarios force the planner to take into account different conditions. The complex structure and preservation requirements of historic buildings do not exclude the possibility of temporary non compliance with current legislation.

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PRESERVATION AND SAFETY PROBLEMATIC FOR THE SAFEGUARD OF THE HISTORICAL HERITAGE

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Key words: preservation, monitoring, museum, safety

ABSTRACT

The preservation of historical, artistic and cultural heritage gives rise to problems of different, and sometimes conflicting, nature. On the one hand there is the need to maintain the goods in very good conditions both from the microclimatic and the safety point of view; on the other hand there is also the strong need to improve as much as possible the conservation procedures for preserving goods and the exposure environment, which must be comfortable also for visitors. It must be added that, particularly in Italy, museums are often located in historical buildings with a high architectural value, for which any intervention aimed at modifying the consistency of the construction elements and technological plants, must be carefully weighted, planned and realized in order to minimize the impact on the whole building. A contribution on the above mentioned problems has been given through the activities carried out by ITC-CNR in collaboration with the company “Borini Costruzioni” in the framework of a project supported by the Italian Ministry for University and Scientifics Research. The paper presents some of the results obtained with the activities carried out in different typologies of Italian museums.

1. INTRODUCTION

The safety problem takes on a considerable importance in the safeguard of goods kept in museums. The mass fruition, with all the issues related to the need to make the works of art enjoyable for the visitors, has remarkably complicated the safeguard and conservation tasks.

It is in this context that the necessity comes out to define and optimise innovative instruments and techniques able to ensure the conservation safety and quality.

In the context of the MIUR (Italian Minister for Instruction University and Research) project “Technologies of improvement of the active and passive safety for goods held in the building and for the visitors”, assigned to the company Borini Costruzioni where ITC-CNR collaborated, four research projects were carried out.

They allowed in particular:

- the conceiving, realisation and experimentation of an innovative system for the fire protection of the exposed works of art;
- the conceiving, realisation and experimentation of an innovative system for the public quick evacuation, in case of fire, from collective use buildings;
- the conceiving, realisation and experimentation of a single system for the protection of the exposed works of art from the effects caused by earthquakes;
- the conceiving, realisation and experimentation of an innovative integrated system for the monitoring of the environmental parameters of museums.

The results and the final products of these research projects are synthetically reported in the paper, where the most widening is for the environmental parameters monitoring integrated system, studied, realised and experimented in some museums of the “Abruzzo” Region.

All the systems developed and realised have such characteristics as can be produced in small series and to be customisable depending on different requirements, with competitive production costs as regards the Italian market.

2. INNOVATIVE SYSTEM FOR THE FIRE PROTECTION OF THE EXPOSED WORKS OF ART

It is a fire protection system for exposed works of art, made up of an autonomous and self-sufficient device of physical-mechanic protection of the exposed object. It guarantees the highest flexibility, since it is adaptable to contain works of art with different dimensions and characteristics.

It is made up of mechanical, electric and electronic devices, which are modular and applicable to each realisation, and an external envelope with a design that can adapt to each environment and fitting out.

The system integrates the general system of surveying, signalling and fire extinction already installed in the building open to the public, for any typology and working configuration, ensuring the protection of the work of art for at least 30 minutes, independently from the correct functioning of the overall fire protection system of the exhibition area.

The device is conceived to be provided with auxiliary equipment to preserve the work of art from vandalism, thefts and inadequate conservation conditions and with the possibility to be integrated with earthquake protection devices. The system is also equipped with air conditioning plants able to maintain the thermo-hygrometric parameters at optimal conditions.

Concerning the prototype, a device has been realised and experimented (Fig. 1) to contain paintings having dimensions up to 2m x 1m, with characteristics of easy installation and maintenance at present installed in S. Chiara Museum at Sulmona (AQ).

Fig. 1. Innovative fire protection system (realised by Borini Costruzioni)

3. INNOVATIVE SYSTEM FOR THE PUBLIC QUICK EVACUATION, IN CASE OF FIRE, FROM COLLECTIVE USE BUILDINGS

It is a system that allows the quick and safe public evacuation from collective use buildings, as an integration of what already foreseen by the law in force, therefore able to improve the public security.

It can be applied in all the cases in which, because of environmental and historical-artistic bonds, the building can't be equipped with traditional evacuation system such as internal emergency staircases or external security staircases.

In short, it is made up of a helicoidal staircase built of light and fireproof alloys, that, when not in use, is folded and closed in a small-size box whose shape and appearance can easily be integrated in the architectural context of every construction typology.

It is provided with a mechanical device which operates autonomously or through the building warning systems, also when the electric power is not available. Such a device causes: the opening of a panel, that faithfully reproduces the original façade, the horizontal translation of the staircase towards the outside and its extension downwards; the staircase, propped up by a central pantograph and by an analogue external structure, is a real escape way to convey people towards a safe place.

The prototype was operatively validated through installation and use in three valuable historical buildings, that is the "S. Chiara" Diocesan Museum (Fig. 2) and the "SS. Annunziata" Civic Museum in Sulmona (AQ) and the "Fanzago" Palace in Pescocostanzo (AQ).

In all these cases specific attention was drawn to the issue related to the integration in monumental buildings.

Fig. 2. Innovative system for the public quick evacuation (realised by Borini Costruzioni)

4. INNOVATIVE SYSTEM FOR EXPOSED WORKS OF ART PROTECTION FROM THE EFFECTS CAUSED BY EARTHQUAKES

It is a single protection system prototyped for works of art with largest dimensions 80 x 80 x 80 cm, but it will be however reproducible on small industrial series for objects having different inertia and volume. It is made up of an anti-quake support, easily and quickly installable, including a mechanical part made up of a set of “wire rope” isolators and reversible systems for fixing the objects exposed to the showcase base.

The earthquake protection system is completed and integrated with air-conditioning plant installed inside the prototype, based on Peltier cells system and able to maintain the optimum thermo-hygrometric conditions.

The external envelope, made up of appropriate coverings, is studied to be adaptable to the specific aesthetic needs according to the different exhibition contexts and it also accomplishes the passive earthquake protection task for the exposed object, protecting it from partial collapse of the building.

(Fig. 3) was first of all operatively validated by means of tests on a vibrant table with six degrees of freedom, simulating, for different work of art typologies, the most frequent earthquakes spectrograms and relative evolution, as well as the most relevant Italian earthquakes spectrograms of the last decades; afterwards the validation was completed by the installation of the prototype in a building containing works of art and located in a seismic area.

Fig. 3. Innovative system for exposed works of art protection from the effects caused by earthquakes during normal working conditions and after a warning situation (realised by Borini Costruzioni)

5. INNOVATIVE INTEGRATED SYSTEM FOR THE MONITORING OF THE ENVIRONMENTAL PARAMETERS OF MUSEUMS

The aim of the project was to study and define techniques and equipment for the control and the management of indoor parameters and technological plants in museums through adequate regulation logic implementing mathematical models that can take place at an early stage in order to minimize the effects of particular conditions of risk for the goods. A mathematical model allows to simulate the trend of the microclimatic parameters in the considered museum, as a useful tool for the diagnosis and the definition of adequate intervention strategies.

It is an integrated monitoring system for the environmental parameters affecting the indoor environmental quality both as regards the goods conservation and the visitors comfort, specifically dedicated to museums.

The system allows to control and to adjust the environmental parameters depending on the pre-existing technological plants arrangement and typologies, acting in real time for the diagnostic of any danger conditions for the conserved goods.

The integrated system allows to correlate causes and effects, that is independent and dependent variables that characterise the building thermal, light and energy performances, to verify the energy efficiency of the building-plant system and to control, over the time, the efficacy of maintenance interventions on the construction or plant's elements.

The prototyped system was firstly operatively validated through a series of laboratory meaningful tests to verify the hardware and software components performances, and subsequently through experimentation under real working conditions in three museums (in L'Aquila and Sulmona), which differ from each other as concerns the building and plant consistency and typology of contained goods.

Fig. 4. Prototype of innovative integrated monitoring system during the museum room preparation phase (realised by ITC-CNR)

5.1. Main characteristics of the monitoring system

The system mainly consists of hardware and software components. The HW has been conceived to facilitate as much as possible the acquisition of the microclimate data and the active control in particular of the plant devices and actuators able to maintain an adequate level of indoor microclimate quality through the control of its characteristic parameters (temperature, humidity, illuminance, presence of chemical and organic pollutants, ...).

The system configuration includes a central station for the control and the management of ambient parameters and some peripheral stations to which the sensors for the measurements of the ambient parameters are connected. These peripheral stations can be connected to the central one in different ways. One of the characteristics of the system is the possibility to arrange a monitoring network through the remote sensors, each connected to a small micro data-logger, designed to allow data acquisition, analysis and transmission.

The system software is structured in different components, meeting different needs such as monitoring, data analysis and active control. Data acquired through monitoring are recorded into a specific database, from which at all times information can be read to obtain the historical trends of the acquired parameters. Besides, the database represents the basis for the analysis and control operations. Through the regulation logic set in the software, the input data are correlated and processed to verify any anomalies or situations classified as risk-situations for goods. If the system is configured to directly act on the plants, the control logic drives the devices needed to obtain the desired effect, ensuring in this way a monitoring and active control system.

The software component allows to create one or more synoptic tables to display in real time the state of the monitored microclimate. Besides, the software manages a mathematical model able to characterise the museum. On the basis of an analysis of the acquired data that could be carried out with a frequency set by the user, the software extracts the values needed to define the thermo-dynamic behaviour of the building. For what concerns the simulation, parametric *black-box* models have been used. The main characteristic of the system is the high degree of flexibility allowing its self-adaptation to different real conditions, using different communication systems between the sensors and the stations, radio or wire communication (RS 232 and RS 485). This allows to choose, depending on the case, the kind of communication implying the minimum impact on the controlled environment, under the same reliability conditions.

The system modularity allows to scale the intervention on the specific needs. It is possible to make a pre-diagnosis of the site through some micro data-logger stand alone supplied by a battery, as independent units able to store the acquired data. Their memory units can be later run down and the data analysed to obtain useful information in order to set up the complete monitoring system. In some cases data acquired during this pre-diagnosis phase can prove to be adequate to characterise the building system and its plants, allowing, if needed, to promptly intervene in a short time.

The efficiency of the technological plants devoted to the conservation and safety, depends also on the regulation and control typology. For conservation, the fundamental element is the plant control (HVAC, lights, ventilation, …) responsible for the setting up of a specific microclimate, in particular for what concerns the temperature, humidity, air quality, illuminance, etc.; for safety, once the meaningful parameters have been identified (temperature for fire issues, vibration for earthquake events, …), it is possible to use the same active control concepts developed for microclimate regulation. Of course the algorithms with which such active control is put into practice are of different nature, from simple on/off to fuzzy type logic and the use of specific mathematical models.

Finally the defined regulation algorithm could be implemented in a BMS device (Building Management System) to manage in an integrated way the conservation and safety issues.

6. A CASE STUDY

A first prototype of the system was installed in the National Museum of Abruzzo located in the XVI century castle in L'Aquila, where it was tested and optimised in its main parts. This museum typology is not a particularly sophisticated solution for what concerns the plant, reflecting however a situation which is typical of most museum typologies in Italy.

The intervention has concerned the section of Modern art, in which paintings and sculptures realised with different techniques are kept. The system has been remotely managed (via phone and modem) from ITC-CNR laboratories in San Giuliano Mil. where the correct behaviour of sensors and devices was controlled by introducing all necessary corrections of the set parameters.

A first phase of pre-diagnosis carried out through a "light" monitoring allowed to point out a set of information on the quality of the microclimate inside the museum, by evaluating at the same time the building/plant system's dynamics. The processing of data acquired during this phase allowed to define homogeneous areas in which fixed sensors were afterwards placed. These sensors were used in the final intervention phase during which the main decay agents were monitored, such as thermal and hygrometric conditions, UV radiation, air quality.

Fig. 5. Pre-diagnosis phase in the Municipal Picture-gallery

Afterwards the system was installed in the Diocesan Museum and the Municipal Picture-gallery in Sulmona (AQ). In the Diocesan Museum, characterised by extremely sophisticated plants, textiles, jewellery, paintings on wood, stone findings, wooden structures and paintings on canvas, realised from the XI to the XVI centuries, are kept; the Municipal Picture-gallery mainly hosts paintings and sculptures of contemporary art, except some works dating back to the end of the XIX and the beginning of the XX century.

The intervention in the Diocesan Museum was divided into three main phases: summer, autumn and winter. After the pre-diagnosis phase, a series of anomalies were pointed out, in particular for what concerns the plants installed in the studied building. After investigating and working out such discovered irregularities, the real diagnostic intervention was started.

6.1. The active control of the plants

The active control of the plants was carried out by implementing three different logics in the software: on/off; PID (Proportional, Integral, Derivative); fuzzy. Any other control logic, for example defined by using the output of the mathematical model, could have been implemented. The three above mentioned logics can use any parameter acquired by the system and recorded in the database as input, giving as output quantities depending on the kind of actuator to be controlled (for ex. % of a shutter opening).

Among the mentioned ones, the Fuzzy Logic was used; it is a kind of logic whose aim is to control the processes through the knowledge of an expert. In fact the intervention strategy is based on such knowledge implemented through appropriate linguistic rules. Unlike the Boolean logic, that only envisages true or false cases, fuzzy sets also envisage shared elements: one magnitude can belong at the same time, strictly or broadly, to different sets.

In particular, the museum site of S. Chiara in Sulmona, in which the intervention was carried out, had two stations, one for heating and one for air-conditioning. Some rooms of the museum were heated by fan-coils, while others by an air-plant. Such rooms were subjected to a close investigation, which took into account their relevance within the museum. The conditioning unit (heating and cooling) was regulated by an existing system that, besides the internal thermostats, used as input data also the temperature and the air humidity in the return ducts, that defined the level of sensible and latent heat on which the conditioning unit had to intervene.

The control of the shutters for the mixing of external and recycled air was carried out, by replacing the manual potentiometer with an electronic board remotely managed by the realised system. Fig. 6 illustrates a scheme of the system for the circulation of the thermal vector.

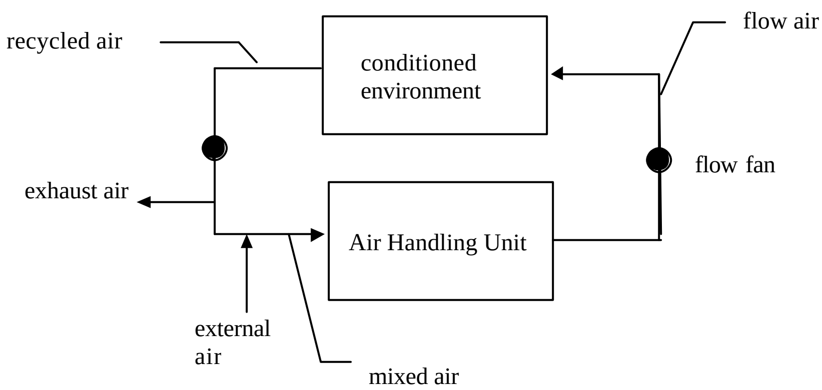

Fig. 6. Scheme of the mixing between external and recycled air

The action carried out on “shutter” elements allowed to act in series with the existing regulation, thus facilitating its functions.

As expected with this kind of logic, three steps of *fuzzification*, *inference* and *defuzzification* were applied. Unlike traditional schemes, where a numerical value (for ex. T=25 °C) is associated to each input or output variable (for ex. temperature), this logic used linguistic terms (for ex. hot, warm, cold, very cold, ...) representing the possible values. Each linguistic term was identified by a fuzzy set, defined by a belonging function f(x). In this way each variable could belong to more linguistic terms (and more sets) with different belonging degrees ?(x). The variables to be controlled and their variability interval were: relative humidity (lower limit 0% upper 100%), relative humidity difference (-50 and 50), temperature difference (temperature (-30 and 30). The output was the only variable: external shutter opening (0 and 100%).

Having defined the variables, the linguistic terms with their sets and the belonging functions, the rules were fixed, rules being the conditions on the input (IF...) and the output (THEN) variables. The control logic was defined through these rules: the software read from the database the values of the inputs at moment t and, by applying the belonging functions, estimated for each variable, the belonging degree for each set, applied the fixed rules and did not provide an univocal output value but a certain number of valid rules, with different validity degrees, to which various conclusions about the outputs corresponded.

To obtain just one output value, in this case the opening degree of the shutter, the defuzzification phase was needed. Through such phase it was possible to move from "linguistic" conclusions about the output to numerical conclusions using the method of the maximum centre (CoM). Being the output the opening degree of a shutter managed by a potentiometer, the output value was brought near the integer or a multiple of five or ten, to be defined and translated in volt.

The application of the fuzzy logic allowed to regularise and optimise the control of the indoor microclimate.

6.2. The mathematical model

In addition to the control of the plants, the software of the system managed a mathematical model that allowed to characterise the thermo-dynamic behaviour of the museum.

For the simulation, a parametric *black-box* model was used. This kind of model doesn't comprise any physical description of the building, but is identified by analytical parameters that allow to define a link between inputs (for ex. external temperature, solar radiation, external hygrometric degree, air leakage, ...) and outputs (internal temperature, internal hygrometric degree, ...) through linear differential equations.

The general formulation of a parametric model, that is a model parameterised by a vector ? estimated through the analysis of the relation between inputs and outputs, is:

$$y(t) \; ? \; G(q^{?1};?) \; ?u(t) \; ? \; H(q^{?1};?) \; ??(t) \qquad (1)$$

where:

y(t): output whose dimension is ny;

u(t): input whose dimension is nu;

?(t): white noise;

$G(q^{-1},?)$ e $H(q^{-1},?)$: matrix containing rational functions of ?, whose dimensions are (ny x nu) and (ny x ny);

q^{-1} : delay or shift operator defined as follows:

$$q^{?1}u(t) \; ? \; u(t \; ? \; 1) \qquad (2)$$

In the considered case, among the different typologies of parametrical black-box models (AR, ARMA, ARX, ARMAX, …), to be used to characterise the building, the ARX (AutoRegressive eXogenous Inputs) model was chosen, that can be written as follows:

$$y(t) + a_l ? y(t - ?) + a_2 ? y(t - 2?) + a_3 ? y(t - 3?) + \ldots + a_{na} ? y(t - n_a?) =$$
$$b_{11} ? u_l (t - n_{k1}) + b_{12} ? u_l (t - n_{k1} - ?) + \ldots + b_{l,n1} ? u_l (t - n_{k1} - n_1? + 1) +$$
$$\ldots$$
$$b_{ml} ? u_m (t - n_{km}) + b_{m2} ? u_m (t - n_{km} - ?) + \ldots + b_{m,nm} ? u_m (t - n_{km} - n_m? + 1) \qquad (3)$$

Where:

y is the output (for ex. internal temperature);

$u_1 \ldots u_m$ are the input (for ex. external temperature, solar radiation, ...);

$a_1 \ldots a_m$ are the coefficients (numerical parameters) of the output;

$b_{1,1} \ldots b_{m,nm}$ are the coefficients (numerical parameters) of the input;

n_a is the order of the outputs;

$n_1 \ldots n_m$ are the orders of inputs (that is how many inputs are needed to determine the output);

$n_{k1} \ldots n_{km}$ are the delays of inputs (that is starting from which temporal step the inputs have to be considered)

Setting the input coefficients equal to zero, the AR (Auto Regressive) model is obtained. The system is therefore identified as if there were no input. The output depends only on the values of the output itself in the previous moments and on the white noise at time *(t)*.

$$y(t) = - a_l ? y(t - ?) - a_2 ? y(t - 2?) - a_3 ? y(t - 3?) - \ldots - a_{na} ? y(t - n_a?) \qquad (4)$$

In the case of the Diocesan Museum the identification phase was carried out on the basis of the experimental data acquired during the monitoring. Two simulation sets were carried out, choosing as output in the former case the internal temperature of air in the rooms, in the latter case the internal relative humidity. The simulations were made by combining in different ways the inputs, that were: external temperature, solar radiation, wind velocity, illuminance, frigories supplied by the cooling plant, calories supplied by the heating plant, external relative humidity.

The analysis of the identification processes related to the various choices allowed to understand the most incisive inputs on the output values. In the case of the internal temperature, the chosen inputs were: external temperature, solar radiation, wind velocity, frigories supplied by the cooling plant.

Once defined the analytical structure of the model through the identification, the model itself was used to foresee the trends of the environmental parameters. Fig. 7 reports the trends of the measured and foreseen output. It shows how the model can foresee the general trend of the real system, even though in is not able to follow sudden changes of the internal temperature values.

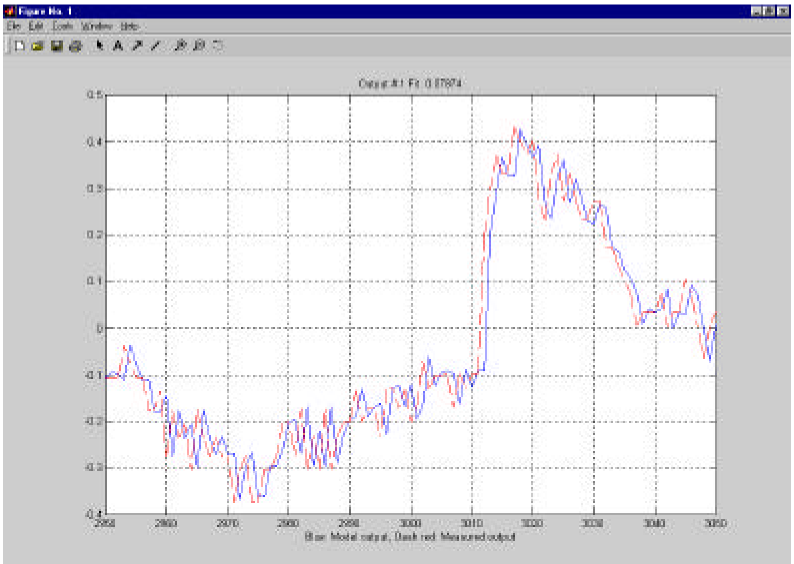

Fig. 7. Diagram real output/simulated output by ARX model

The same experimental data were also used to carry out an application of an AR auto-regressive model which just needed that the output parameters of the system to be identified were known. For the definition of the model it was necessary to set up: the inputs, the model's order (that is how many values of the output in the moments preceding t affect the output value at t) and its delay (a delay equal to n means that the output at t depends on the value that the output assumes in the previous moments till t-nt). A model structure was obtained by setting the delay and the order equal to 1 and 2. Through this model structure the output reported in Fig. 8 was simulated.

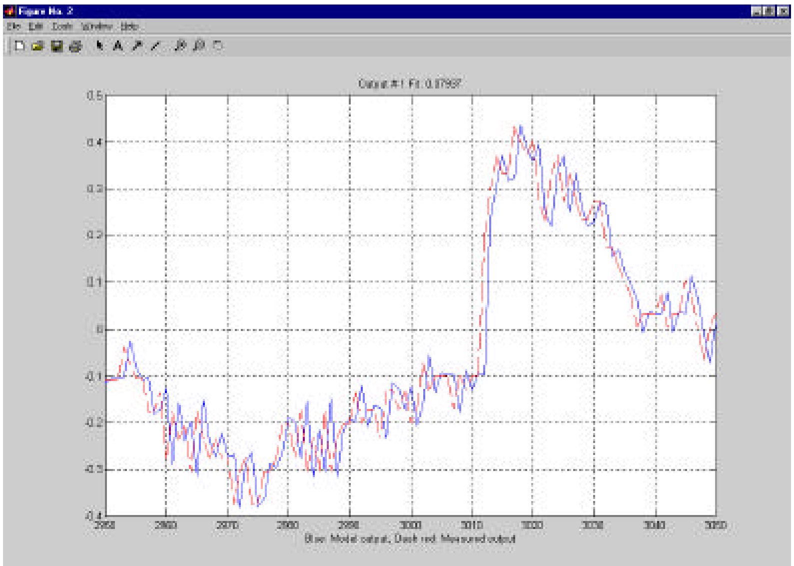

Fig. 8. Diagram real output/simulated output by AR model

Therefore, if the analytical models should be used in the regulation logic (for ex. considering the model's output as one of the inputs of a fuzzy controller), a simple AR model could be used obtaining anyhow fairly good results, through the application of appropriate procedures that need for example a frequent identification of the analytical parameters.

A graphical interface was prepared through MatLab? software to facilitate the identification phase by unskilled users.

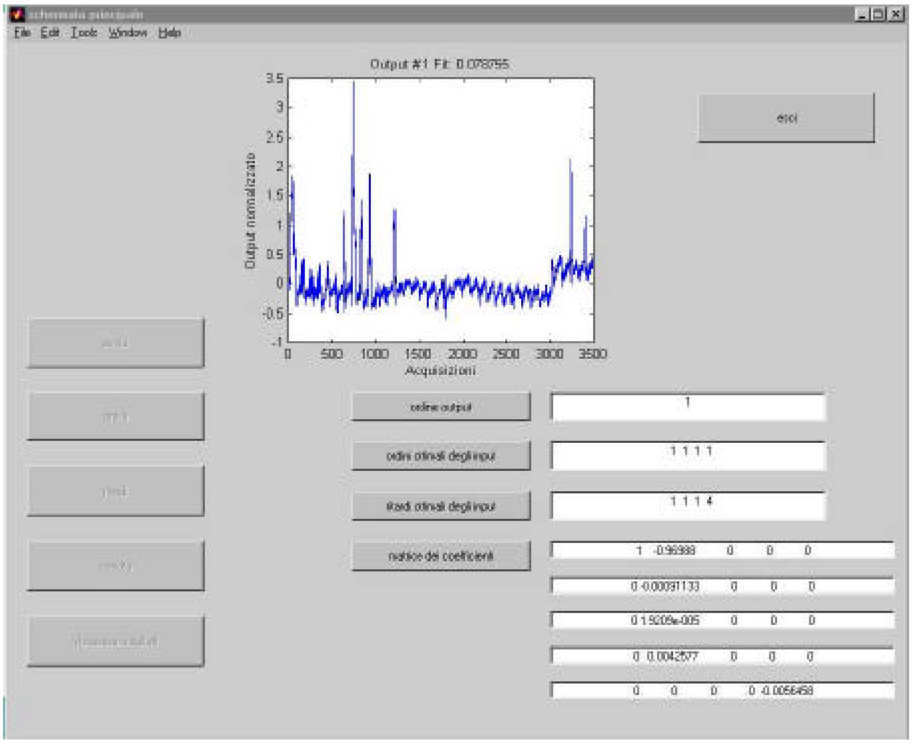

Fig. 9. Window with data displayed

The only actions the user has to perform before starting it are the control of the temporal regularity of the data to be used for the identification (acquisition interval must be constant and no anomalous trend should be recorded) and the removal of any “outliers”, that are data particularly far from the expected and reasonable trend (due to various causes, for ex. measuring errors).

7. CONCLUSIONS

Firstly, it’s quite evident that a rational preservation policy of the historical-artistic heritage cannot be restricted to isolated interventions of conservative restoration, but it must refer to a programme of re-qualification of the environment where goods are kept. A survey on a representative sample of museums revealed that many museums, mainly the smallest or less famous ones, even though they host highly valuable works of art, can rely on no safety control system and in some cases referring to the microclimate, neither on suitable heating systems.

As underlined many times, the quality of the environment is one of the main factors to be considered. Such quality mainly depends on the interaction between the building and the plants installed inside, and the deterioration of the goods or their optimal conservation during the years can depend on such interaction.

Meaningful diagnostic interventions aimed at improving the quality of the goods' conservation can be a result of the coordination of the activities of the different expertise of professionals in charge of the conservation, with both a technical-scientific and humanistic background.

Most frequently the works are exhibited by mainly considering visibility aspects, the same way as the plants are realized without considering the ideal micro-climatic conditions for the work's conservation. It is plain that to reach this goal many efforts are requested from the people involved, who should be more sensitive towards such issues. The activity carried out so far intended to awaken the awareness of the people working in this field, providing them with tools that, as demonstrated, could really contribute to preserve the historical and artistic heritage inside the museum for the longest time, by ensuring at the same time people's safety.

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LA PROGETTAZIONE DEI SISTEMI CLEAN AGENT

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La progettazione dei sistemi Clean Agent, con l'avvento delle alternative agli Halons, richiede una ingegneria più accurata che non nel passato. Molto spesso i progettisti o chi deve scegliere il sistema di protezione antincendio piu' adeguato per proteggere dei beni di alto valore e sensibili agli effetti collaterali dell'agente estinguente si trovano nel dilemma di dover scegliere non solo l'agente estinguente ma anche di dover giudicare se il progetto che riceveranno sia congruente con lo stato dell'arte piu' aggiornato e che risponda agli standard attualmente in forza.

Una serie di estinguenti disponibili sul mercato ed adatti a soddisfare tali requisiti sono i nuovi estinguenti gassosi oggi identificati come "alternative agli Halons"; gli Halons storicamente erano gli estinguenti principe per tali applicazioni.

Il bando, per motivi ambientali, degli Halons ha posto la necessita' di studiare delle alternative adatte alla loro sostituzione.

A tale scopo sono stati condotti studi di ricerca in diverse direzioni, esplorando opportunita' di soluzioni piu' o meno ortodosse. Probabilmente, per la prima volta nella ricerca di nuovi estinguenti, sono stati introdotti dei nuovi concetti sia per l'analisi dei problemi specifici di ogni singolo estinguente che per la ricerca delle soluzioni applicative.

Oggi, dopo anni di ricerca e sviluppo industriale, si e' arrivati alla definizione di due grandi famiglie di alternative agli halons: alternative "in kind" ed alternative "not in kind".

Come si puo' intuire le alternative "in kind" identificano degli agenti estinguenti con caratteristiche molto simili agli Halons, mentre le alternative "not in kind" identificano agenti estinguenti o tecnologie molto diverse che hanno dimostrato di poter efficacemente sostituire gli Halons nelle loro applicazioni. Al momento sono ancora in corso studi, probabilmente nel prossimo futuro ulteriori tecnologie alternative troveranno applicazione commerciale.

Le alternative agli halons piu' utilizzate al momento sono le alternative "in kind", ovvero agenti estinguenti gassosi che si dividono in due gruppi: agenti estinguenti halocarbon, molto simili ai vecchi halons, ovvero gas liquefatti e compressi, e gas inerti, che sono gas compressi. Benche' le due tecnologie abbiano alcune caratteristiche diverse sono state accomunate con la denominazione "clean agent"; in quanto il loro uso non comporta rischi di danni collaterali o rilascio di residui dovuti all'agente estinguente.

I sistemi a clean agent ovvero gas sono utilizzati per la protezione di spazi contenenti oggetti di grande valore o per proteggere equipaggiamenti, impianti o informazioni critiche.

Le applicazioni tipiche sono: Telecomunicazioni, Elettronica, Sale computer, Sale Controllo Sale Macchine.

Gli standard internazionali di riferimento per la progettazione di impianti utilizzanti gas estinguenti sono:

ISO 14520 1/15 Gaseous fire-extinguishing systems First Edition August 2000

NFPA 2001 Standard for Clean Agent Fire Extinguishing Systems 2000 Edition

UL 2166 Standard for Halocarbon Clean Agent Extinguishing Systems Units, First Edition March 31, 1999

UL 2127 Standard for Inert Gas Clean Agent Extinguishing System Units, First Edition March 31, 1999

CEN prEN 14520 1/15 Fixed Firefighting Systems Gas Extinguishing Systems

UNI 10877 1/15 Sistemi di estinzione incendi ad estinguenti gassosi, Aprile 2000

Gli standard citati non includono l'anidride carbonica, che e' coperta da specifiche norme, in quanto in uso da moltissimo tempo e che non puo' essere accomunata agli altri gas estinguenti poiche' i parametri di utilizzo specifici relegano l'anidride carbonica al solo uso in aree non occupate da persone.

La corretta progettazione degli impianti e la loro affidabilita' e' influenzata da alcuni parametri critici quali:

?? Concentrazioni di estinzione (Extinguishing Concentrations)

?? Fattori di Sicurezza e di Progetto (Safety/Design factors)

?? Concentrazioni massime di Esposizione (Concentration/Exposure Limits)

?? Programma computerizzato per la progettazione (Design Software)

?? Decomposizione Termica (Thermal Decomposition)

?? Ritenzione dell'agente estinguente nel volume protetto (Agent Retention)

?? Sovrappressione del volume protetto e superficie di rilascio (Enclosure Pressure and Venting)

Il processo di estinzione dei clean agents avviene per i seguenti fenomeni:

?? Incremento della capacita' termica dell'ambiente in cui si sviluppa il fuoco, risultante in un aumento della quantita' di energia necessaria per innalzare la temperatura dell'aria comburente alla temperatura delle fiamme.

?? Diluizione dell'ossigeno, con conseguente ridotta produzione di calore.

?? Per reazione endotermica (assorbimento di energia) per reazioni di decomposizione dell'agente estinguente in presenza di elevato calore (fiamme). La scomposizione dell' agente estinguente genera dei radicali che catturando ossigeno non lo rendono disponibile per la reazione di combustione.

Gli halocarbons utilizzano tutti i tre meccanismi per incrementare la perdita di calore del fuoco fino al punto in cui l'incendio non e' piu' autosostentato.

I gas inerti estinguono il fuoco riducendo la temperatura dele fiamme al di sotto del livello necessario per mantenere la combustione. Cio' e' ottenuto riducendo la concentrazione dell'ossigeno ed incrementando la capacita' termica dell'aria. I gas inerti non utilizzano il terzo meccanismo.

Determinare le corrette concentrazioni di progetto e' uno degli aspetti piu' critici dei sistemi a gas.
La concentrazione di progetto e' determinata dalla seguente equazione:

DC=(EC x SF) + DF dove:

DC= Design Concentration (concentrazione di progetto)
EC= Extinguishing Concentraqtion (concentrazione di estinzione)
SF= Safety Factor (fattore di sicurezza)
DF= Design Factor (fattore di progetto)

Le concentrazioni di estinzione sono determinate con protocolli di prova e per ogni specifico combustibile da considerare nel progetto.

La concentrazione di progetto si ottiene incrementando la concentrazione di estinzione con l'appropriato fattore di sicurezza (secondo NFPA; ISO; CEN; UNI), ed infine con i fattori di progetto necessari per compensare situazioni particolari dello specifico impianto.

I protocolli per la determinazione delle concentrazioni di estinzione riportati dagli standard citati sono molto simili come metodi e filosofia generale, variando solamente per alcuni dettagli. Tali protocolli di test sono stati sviluppati sperimentalmente e verificati da diversi laboratori pertanto sono considerati rappresentativi della realta' (probabile scenario di fuoco) e ripetibili con grande affidabilita'.

Ad oggi gli standard NFPA e UL sono completati in tutti gli aspetti progettuali, mentre ISO, CEN, UNI sono in corso di completamento formale, per trattare l'argomento in maniera esaustiva si fara' riferimento a NFPA e UL, i rimanenti standard saranno aggiornati, entro pochi mesi, allo stesso livello (con alcune differenze di dettaglio).

DETERMINAZIONE DELLE CONCENTRAZIONI DI ESTINZIONE SECONDO NFPA 2001, 2000 EDITION:

<u>Combustibili di Classe A:</u>

?? UL 2127 e UL 2166
?? Catasta di legno in volume di prova di 100 m3
?? Focolaio di lastre di plastica in volume di prova di 100 m3 (Fig 1).

Il test e' condotto utilizzando 3 tipi diversi di polimeri (PMMA, PP, e ABS). Tali combustibili sono considerati un ragionevole caso peggiore di incendio di Classe A per rischi protetti con Clean Agents.

PMMA = Polymethyl methacrylate; PP = Polypropylene; ABS = Acrylonitrile-butadiene-styrene polimer

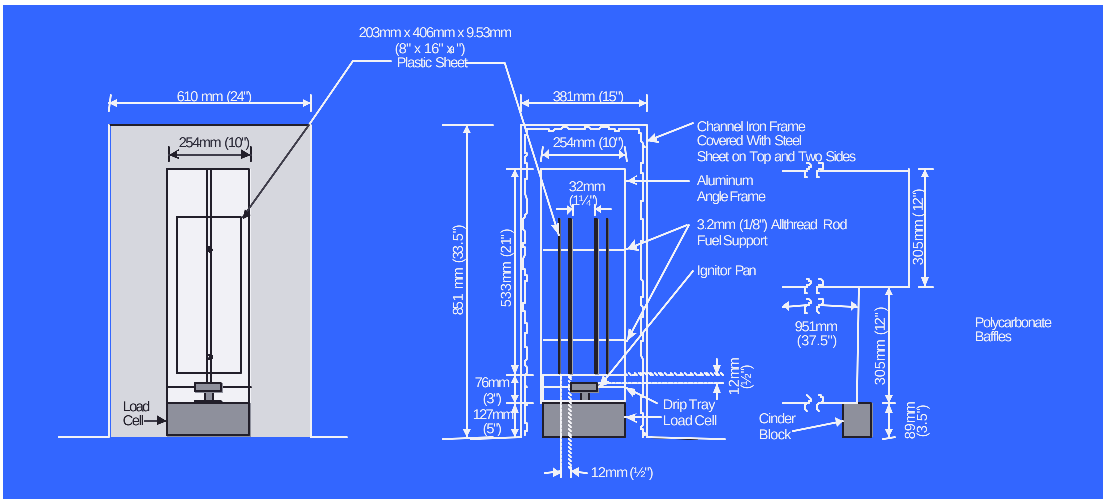


Fig. 1: Focolaio con lastre di plastica secondo UL Class A test

<u>Combustibili di Classe B:</u>

?? Cup burner

?? Test in scala reale (UL and IMO)

Il protocollo IMO include sia vasche che spray fires di eptano e combustibile diesel. Il volume minimo di test e' di 500 m3, l'intensita' di energia sviluppata dagli scenari di fuoco e' elevata.

Il cup burner test consiste in un camino come schematicamente descritto nella Figura. 2, dove una fiamma laminare brucia al sopra di una piccola tazza di combustibile. Il camino e' percorso da un flusso composto da una miscela di aria ed agente estinguente, una appropriata strumentazione consente di misurare la percentuale di estinguente, la minima concentrazione che permette di estingure la fiamma e' la concentrazione di estinzione di quell'agente estinguente per quel combustibile.

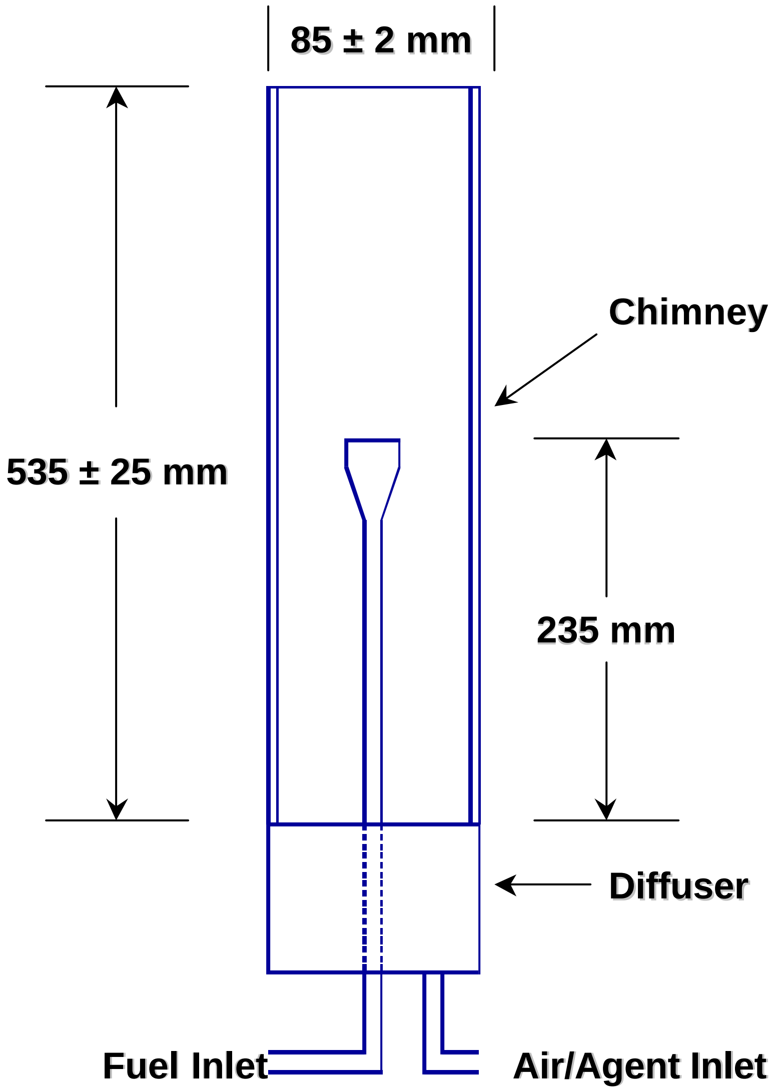


Fig 2: Apparato Cup Burner

Un inconveniente del cup burner test e' la variabilita' dei risultati (per lo stesso agente e per lo stesso combustibile) fra i vari laboratori. La standardizzazione delle procedure di test, dell'apparato e della strumentazione, (che sono in corso) rendera' minime tali differenze.

La Tabella 1 riporta la comparazione degli attuali. valori secondo ISO 14520 e valori riportati da diversi laboratori utilizzanti il protocollo ISO.

Tabella 1: Concentrazioni di estinzione per eptano:

Agent	ISO Values	Other ISO Burner Values	Difference (%)
IG-01 (Ar)	37.5	40.8	8.8
IG-1 (N_2)	33.6	30.2	11.3
IG-541	33.8	31.9, 30.6	10.4
IG-55	32.3		
FC-3110	5.9	5.3	11.3
HFC-23	12	12.3	2.5
HFC-227ea	6.6	6.6	0

Esistono alcuni scenari in cui non e' corretto utilizzare le concentrazioni di estinzione determinate con i protocolli standard. Per esempio nel caso in cui si permetta all'incendio di bruciare per lungo tempo prima di procedere alla scarica dell'agente estinguente tutti gli oggetti in vicinanza del fuoco saranno surriscaldati, sia che si tratti di elementi metallici e/o strutture sia si tratti di oggetti di arredamento.

Il fenomeno fornira' energia da irraggiamento di ritorno allo stesso fuoco/incendio, l'energia incrementera' ulteriormente la temperatura delle fiamme, mentre allo stesso momento l'agente tentera' di ridurre la temperatura delle fiamme fino al punto di spegnimento del fuoco.

In questi casi si dovra' aggiungere una quantita' addizionale di agente estinguente per contrastare l'effetto della energia supplementare fornita all'incendio.

Quanto descritto e' un classico caso in cui si dovra' applicare un adeguato fattore di progetto per compensare il problema specifico.
Il fenomeno e' sintetizzato nella Figura 3.

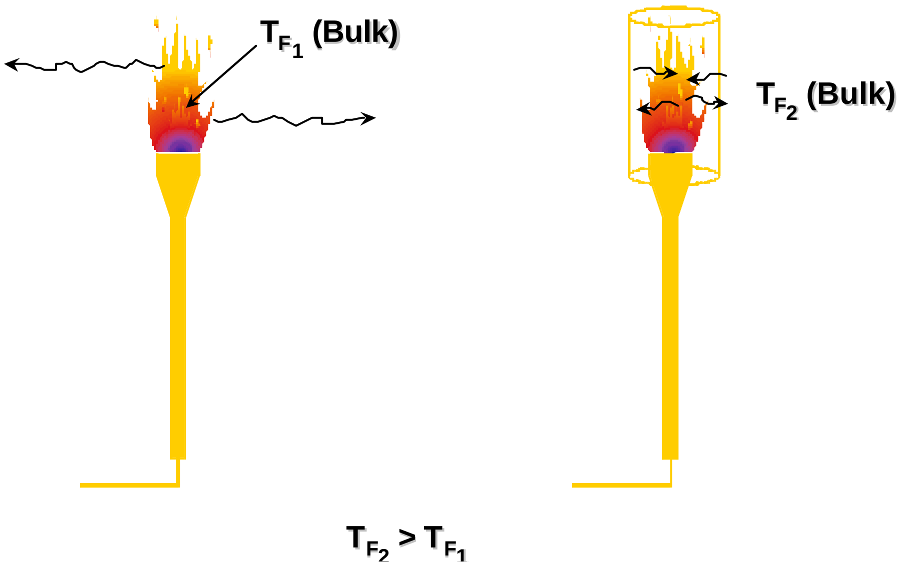


Fig 3

CONSIDERAZIONI CONCLUSIVE SULLE CONCENTRAZIONI DI SPEGNIMENTO:

?? Le concentrazioni di spegnimento sono determinate da test che evidenziano alcune variazioni nei risultati

?? L'energia radiante di ritorno puo' rendere necessario un incremento della concentrazione di spegnimento, cio' e' dovuto da lunghi tempi di preaccensione e dalla presenza di superfici metalliche surriscaldate.

?? Il progettista dovra' determinare la corretta compensazione (fattore di progetto) da applicare in caso di situazioni particolari di rischio.

I fattori di sicurezza:

NFPA 2001, 2000 Edition prescrive:

- 30% – per rischi di combustibili di Classe B, e per sistemi di estinzione attivati manualmente.
- 20% – per rischi di combustibili di Classe A
- 10% – per Inerting
- Design Factors - fattori di progetto aggiuntivi per compensare situazioni di rischio specifiche.

ISO 14520, First Edition (August 2000) prescrive:

- 30% – per rischi di combustibili di Classe A e B
- 10% – per Inerting

La ragione di richiedere un fattore di sicurezza piu' elevato per i sistemi ad attuazione manuale e' dovuto alla possibilita' che prima della attuazione del sistema l'incendio possa bruciare a lungo, con conseguente incremento della energia radiante di ritorno, che come abbiamo visto richiede un incremento della quantita' di agente estinguente.

Un ulteriore beneficio ottenuto incrementando la concentrazione dell'agente estinguente e' la significativa riduzione dei prodotti di decomposizione e di HF rispetto ai dati ottenuti utilizzando le concentrazioni di spegnimento.
Lo standard NFPA considera anche fattori di progetto aggiuntivi per compensare specifiche situazioni di rischio.

I fattori di sicurezza sono utilizzati per incrementare la affidabilita' del sistema di spegnimento, compensando alcune imprecisioni di progetto e/o errori, imperfezioni nel determinare la concentrazioni di spegnimento, ed altre imprecisioni non riscontrate.

Nella ultima edizione delle norme NFPA e' stato introdotto il concetto dei Design Factors (fattori di progetto). Il fattore di progetto e' una quantita' addizionale di agente estinguente che compensa dei fattori di rischio conosciuti dal progettista, che richiedono un incremento della quantita' di agente estinguente. I fattori di progetto sono concettualmente diversi dai fattori di sicurezza, in quanto i primi devono compensare delle situazioni conosciute, mentre i fattori di sicurezza servono per compensare dei problemi che non sono stati evidenziati o riconosciuti.

Alcuni fattori di progetto specifici che si devono considerare generalmente durante la progettazione dei sistemi utilizzanti Clean Agents sono:

?? Numero dei Tee delle tubazioni di distribuzione (numero delle divisioni di flusso).
?? Pressione/livello (altezza sul livello del mare) del volume protetto.
?? Aperture del volume protetto che non possono essere chiuse.
?? Geometria particolare del volume protetto e del potenziale rischio.
?? Ostacoli che possano influenzare la distribuzione dell'agente estinguente.

L'elemento piu' importate del progetto e' il calcolo di flusso del sistema di tubazioni che distribuiscono il gas all'interno del volume protetto. Dovremo far riferimento ai requisiti delle norme NFPA e UL in quanto gli altri standard, al momento, non includono specifici requisiti, che verranno introdotti nella prossima revisione in discussione.

Requisiti di accuratezza (precisione) dei calcoli di flusso (comparazione fra i parametri calcolati e le misure effettuate durante i test di validazione della accuratezza del software):

Halocarbons secondo UL 2166:

?? Massa dell'agente estinguente scaricata da ogni ugello: ±10% con deviazione standard inferiore a 5%

?? Tempo di scarica: ±1 secondo

?? Pressione all'ugello: ±10%

Gas Inerti secondo UL 2127:

?? Volume dell'agente estinguente scaricato da ogni ugello: ±10% con deviazione standard inferiore a 5%.

?? Tempo di scarica: ±10 secondi.

?? Pressione all'ugello: ±10%

IL FATTORE DI PROGETTO PER COMPENSARE INACCURATEZZE DOVUTE AI TEE (DIVISIONI DI FLUSSO)

Lo scopo del fattore di progetto per i Tee e' di compensare le inaccuratezze dovute a flussi di estinguente che passano attraverso diverse divisioni di flusso, in quanto quando un sistema supera il numero di 4 divisioni, non si puo' essere matematicamente sicuri che la accuratezza richiesta dalle norme sia rispettata, pertanto e' necessario procedere ad una compensazione.

Il fattore di progetto per Tee multipli non deve essere applicato se il sistema sara' collaudato con una scarica reale e saranno verificati tutti i parametri critici.

Probabile distribuzione della massa di agente per sistemi contenti da 2 a 20 T:

I due grafici seguenti dimostrano perche' dobbiamo applicare in fattore di progetto per le divisioni di flusso. L'esperienza ha dimostrato che la accuratezza massima e' piu' o meno 5% con una certezza del 90%, significa che il 90% delle misure di quantita' di agente estinguente sara' entro una tolleranza di piu' o meno 5% rispetto ai risultati del calcolo. Assumendo che l'errore abbia caratteristiche random, la probalita' puo' essere rappresentata da una distribuzione Gaussiana. Cio' e' rappresentato dalla curva per 2 Tee (divisioni di flusso), con deviazione standard del 0.0304.

Per sistemi con numerose divisioni di flusso l'errore sicuramente aumentera', e la accuratezza delle previsioni della quantita' di agente scaricato da ciascun ugello diminuira', l'ammontare dell'errore puo' essere calcolato per ogni numero di Tee, il grafico di Fig 4 ne riporta 20.

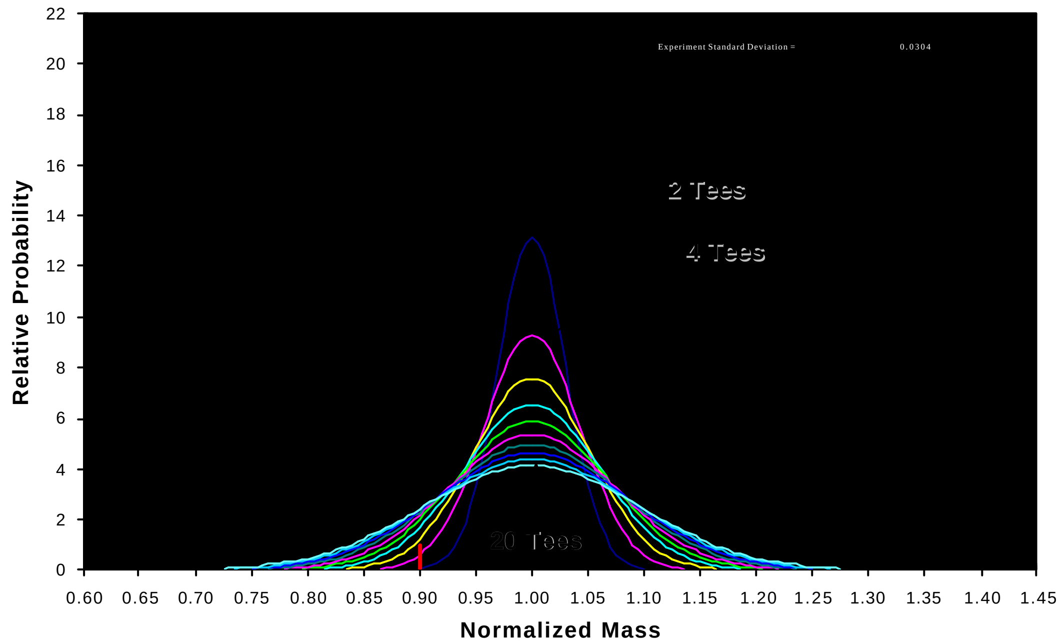


Fig 4

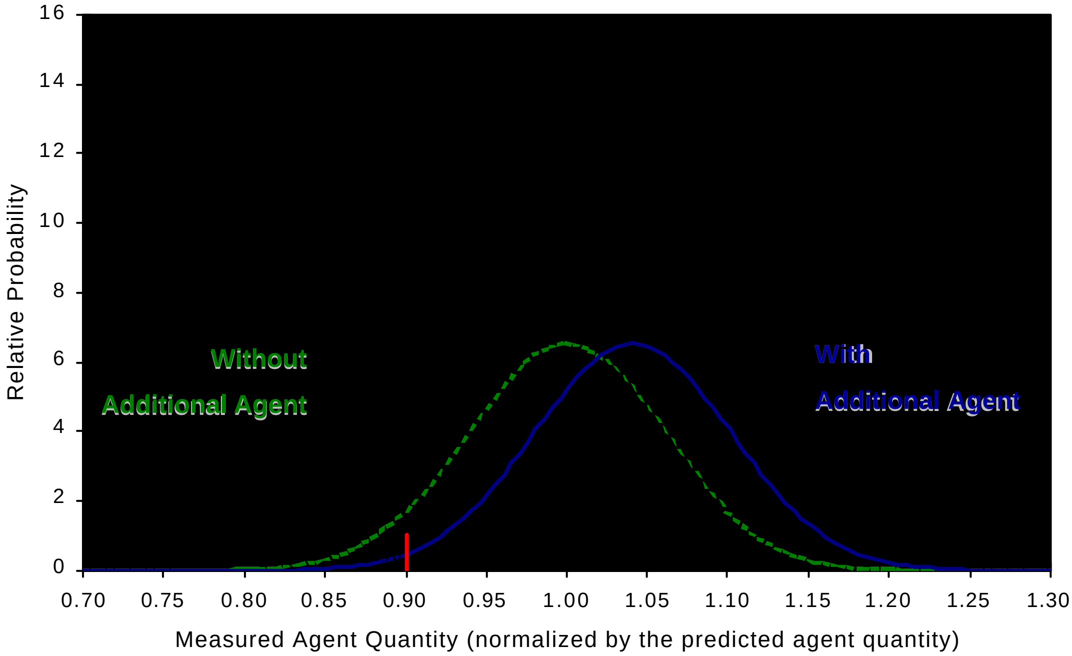


Fig 5: Calcolo della probabile distribuzione della quantita' di agente in un sistema con 8 Tee (deviazione standard = 0.0608)

Si assume che un sistema a clean agent debba avere (come minimo requisito) il 99% degli ugelli che scaricano il 90% della quantita' di agente calcolata. Pertanto sara' utilizzato al massimo 1/2 del fattore di sicurezza per Classe A o 1/3 per la Classe B per compensare il 99% degli ugelli.

Se prendiamo in considerazione un sistema con 8 Tee (Fig 5), per una distribuzione calcolata senza fattore di progetto (deviazione standard 0,0608), l'area della curva rappresentante l'1%del sistema, corrisponde a un valore normalizzato della massa dell'agente di 0,859. Pertanto un numero decisamente superiore del 1% degli ugelli scarichera' meno del 90% della quantita' calcolata di agente. Per compensare il l'inconveniente si dovra' aumentare la quantita' di agente da scaricare. Aumentando la quantita' di agente si spostera' la curva delle probabilita', per esempio per un sistema con 8 Tee la quantita' di agente da aggiungere sara' 4.1% (0,90-0.859), cio' assicurera' che il 99% degli ugelli scarichera' almeno il 90% della quantita' di agente calcolata.

Fortunatamente non sara' necessario eseguire calcoli complessi, lo standard NFPA contiene i valori gia' calcolati. I fattori di progetto per i gas inerti sono inferiori dei fattori per halocarbons, cio' e' dovuto al fatto che il flusso dei gas inerti e' calcolabile con maggiore accuratezza essendo un flusso in singola fase e che inoltre e' meno sensibile alla imprecisioni dei tubi.

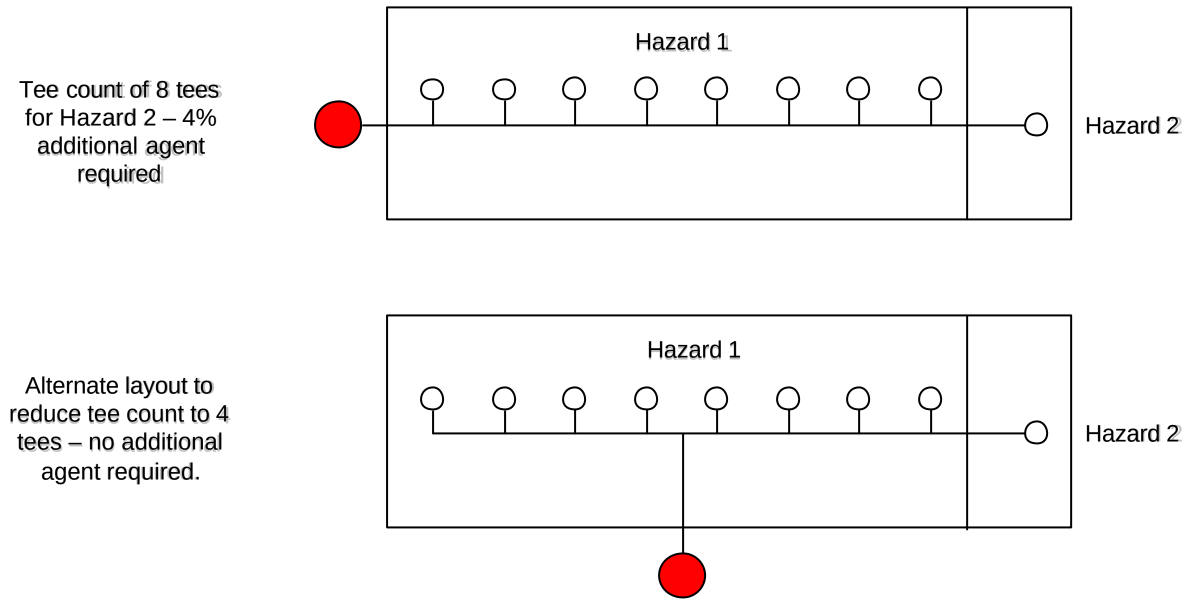
Tabella 2: Fattori di progetto per T

DESIGN FACTOR TEE COUNT	HALOCARBON DESIGN FACTOR	INERT GAS DESIGN FACTOR
0-4	0.00	0.00
5	0.01	0.00
6	0.02	0.00
7	0.03	0.00
8	0.04	0.00
9	0.05	0.01
10	0.06	0.01
11	0.07	0.02
12	0.07	0.02
13	0.08	0.03

Esempio:

Il primo grafico mostra cosa puo' accadere se il numero dei Tee non e' stato considerato. Gli ugelli del Rischio 1 scaricheranno piu' agente che la quantita' calcolata, ed in Rischio 2 alla fine della linea no ricevera' agente sufficiente, il fattore di progetto per Tee serve per compensare il probelema.

Si potrebbe ridurre il fattore di progetto per Tee spostando lo stoccaggio (bombola) dell'agente estinguente in una posizione piu' favorevole o addirittura vicino al rischio 2.



Fattore di progetto per compensare la pressione (altezza sul mare) del volume protetto

- ?? La quantita' di agente estinguente deve essere compensata se la pressione ambiente (ovvero altezza sul mare) del volume protetto varia piu' dell'11% dalla pressione standard a livello del mare.
- ?? Esistono altre situazioni in cui la pressione dell'ambiente protetto puo' essere diversa dalla pressione standard a livello del mare ad esempio in camere iperbariche, miniere, o installazioni dove per necessita' particolari viene creata una atmosfera artificiale con pressioni piu' alte o inferiori alla standard.
- ?? Negli standard sono contenuti tavole con coefficienti di correzione.

Fattori di progetto addizionali

Situazioni particolari del rischio protetto devono essere accuratamente valutate per poter formulare un progetto corretto del sistema di protezione. Questa necessita' non e' specifica dei soli impianti a clean agent, ma in generale di tutta la scienza antincendio, per questo motivo qualsiasi progetto di protezione deve essere eseguito da persona esperta e competente, certificato da una terza parte qualificata ad eseguire queste valutazioni, in particolare per progetti di protezioni utilizzanti Clean Agents. Nessun standard, ovviamente, puo' contenere tutte le casistiche particolari e specifiche delle piu' disparate applicazioni e rischi, questa conoscenza fa parte del bagaglio di esperienza del progettista.

Alcuni fattori di progetto addizionali ricorrenti sono:

?? Aperture del volume protetto che non possono essere chiuse: sono compensate con una quantita' aggiuntiva di agente estinguente che compensera' la quantita' persa, o con un sistema con scarica prolungata di agente estinguente.

?? Particolari geometrie del volume protetto o del combustibile: sono compensate con ugelli di scarica addizionali e/o una quantita' addizionale di agente estinguente.

?? Test in scenario reale su grandi volumi e complesse geometrie, come ad esempio nelle sale macchine delle navi secondo il protocollo IMO, hanno dimostrato che con geometrie complesse e presenza di ostacoli, la concentrazione dell'agente estinguente non e' omogenea, e puo' variare anche di piu' o meno 20% in diversi punti del volume.

?? Ostruzioni ed ostacoli come: condotti, cavi, apparecchi di illuminazione, etc. possono ostacolare il raggiungimento di una concentrazione omogenea di estinguente nel volume protetto, e devono essere compensati riducendo il coverage degli ugelli, quindi aumentandone il numero.

Limiti di concentrazione ed esposizione delle persone agli agenti estinguenti:

?? E' necessario come linea di principio, evitare esposizioni agli agenti estinguenti non necessarie, a tale scopo devono essere installati, quando necessari, sistemi di ritardo della scarica, per permettere l'evacuazione del personale dal volume protetto, e dispositivi ottici e sonori di attivazione allarme e scarica all'interno ed all'esterno del volume protetto.

?? Per clean agent halocarbon le concentrazioni ammesse massime per le persone sono valutate in funzione della sensibilizzazione cardiaca, utilizzando il protocollo di Reinhardt. Gli acronimi utilizzati per le definizioni sono:

?? NOAEL-No Observable Adverse Effect Level (massimo valore di esposizione all'agente estinguente ovvero concentrazione, a cui non vengono riscontrati effetti collaterali)

?? LOAEL-Lowest Observable Adverse Effect Level (minimo valore di esposizione all'agente estinguente ovvero concentrazione a cui vengono riscontrati effetti collaterali)

?? PBPK- Physiologically-Based Pharmacokinetic, model che considera la concentrazione massima ammissibile nel sangue dell'agente estinguente ed il tempo necessario per raggiungerla.

?? Per i gas inerti le concentrazioni massime ammesse per le persone sono valutate misurando l'ossigeno residuo nell'ambiente dopo la scarica dell'agente estinguente, pertanto:

?? Una concentrazione di ossigeno residuo del 12% viene assunta come valore di NOAEL

?? Una concentrazione di ossigeno residuo del 10% viene assunta come valore di LOAEL

?? Il protocollo PBPK non e' applicabile ai gas inerti.

Concentrazioni massime di utilizzo:

?? Per aree normalmente occupate:
?? Halocarbons
?? Fino al NOAEL
?? Fino al LOAEL con applicazione dei tempi di esposizione ammessi dal PBPK
?? Per gas inerti
?? Fino al 43% (%v/v) corrispondente al 12% di ossigeno residuo, con una esposizione massima di 5 minuti
?? Per aree normalmente non occupate:
?? Halocarbons.
?? Fino al 24% (16%di ossigeno residuo) limitando la possibile esposizione entro i tempi ammessi dal protocollo PBPK.
?? Per gas inerti:
?? Fino al 52% (10% di ossigeno residuo) limitando la possibile esposizione a non oltre 3 minuti.
?? Fino al 62% (8% di ossigeno residuo) limitando la possibile esposizione a non oltre 30 secondi.

Se il volume protetto non e' fisicamente occupabile da persone non ci sono limiti alla concentrazione massima.

Il software di calcolo di flusso del sistema

Il programma di calcolo di flusso serve per dimensionare correttamente il sistema a clean agent; in particolare deve determinare con accuratezza i tempi di scarica, la pressione agli ugelli, e la quantita' di agente scaricato dagli ugelli.

In generale gli impianti non sono verificati con test di scarica, pertanto il programma di calcolo e' il mezzo che permette di assicurare la corretta realizzazione del sistema di protezione, secondo i requisiti degli standard di riferimento e della buona ingegneria. Al momento lo standard e le autorita' di listing che fanno riferimento a precise caratteristiche del programma di calcolo sono NFPA e UL, gli altri standard sono in corso di completamento.

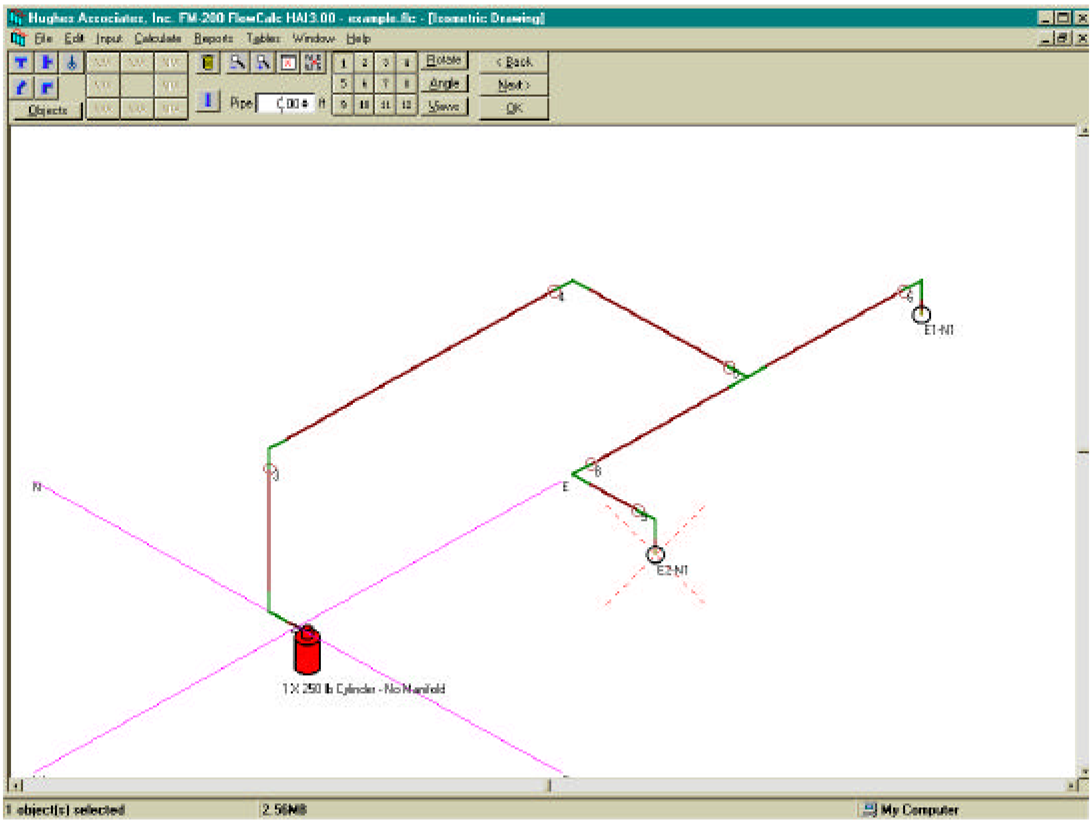


Fig 6: Esempio di schermata di un programma di calcolo per sistemi utilizzanti HFC 227 ea

Il programma di calcolo non puo' considerare o risolvere qualsiasi problema di progettazione, pertanto deve essere utilizzato da un progettista competente e deve contenere limiti e messaggi di errore per prevenirne un uso non corretto. Il programma di calcolo deve essere ovviamente certificato da un laboratorio indipendente che ne assicura la validita', usualmente per il mercato americano i laboratori di riferimento sono UL e FM (ma non esclusivamente) che accettano e certificano i programmi di calcolo.

Tutto cio' assicura ragionevolmente che il programma di calcolo e' adeguato ai requisiti necessari per soddisfare le necessita' di una corretta progettazione.

Tutti i software di calcolo sono riferiti ad uno specifico hardware, ovvero sono dedicati e sviluppati a precisi componenti di impianto.

Alcuni programmi anno la capacita' di poter acquisire o trasferire il layout delle tubazioni a programmi CAD, inoltre alcuni hanno la capacita' di accettare suggerimenti o dati imputati dal progettista (ad esempio diametri di sezioni di tubo) caratteristica molto utile per eseguire retrofit su impianti esistenti.

Un programma di calcolo pertanto deve possedere le seguenti caratteristiche:

?? Validazione (listing o approvazione) da parte di un laboratorio terzo.

?? Servizio tecnico di supporto e follow-up prestato da parte della societa' che ha implementato il software.

?? Utilizzo di hardware di impianto (componenti) di qualita' e caratteristiche adeguate (componenti meccanici certificati).

?? Deve contenere limiti matematici di applicazione e messaggi di errore.

Un progetto correttamente eseguito oltre essere eseguito da persone competenti della materia deve essere rivisto ed accettato da un ente terzo e/o da una autorita' avente giurisdizione (che potrebbe anche essere il proprietario del sistema di protezione).

Verifica sperimentale della precisione dei parametri significativi del programma di calcolo.

?? Esecuzione di test di scarica utilizzando diverse configurazioni di tubazioni per verificare se i parametri misurati corrispondono ai parametri calcolati.

?? Esecuzione di test per stabilire i limiti di calcolo quali:

?? Minimo e massimo orifizio di scarica dell'ugello rispetto alla sezione del tubo

?? Tipo di Tee, orientamento dei Tee, e limiti delle divisioni di flusso.

?? Massimo sbilanciamento dell' inizio della scarica dagli ugelli.

?? Massimo sbilanciamento della fine della scarica dagli ugelli.

?? Massimo volume delle tubazioni occupato dall'agente liquefatto verso il volume delle bombole

Come avviene la certificazione di un software di calcolo:

Generalmente avviene in due fasi

Esecuzione di una serie di test sperimentali prima della presenza formale degli enti di listing.

?? Vengono testati alcuni sistemi con 3/4 ugelli.

?? Ogni test deve contenere il piu' grande numero di parametri limite possibile.

?? Tutti i limiti devono essere verificati almeno una volta nel corso dei test.

?? Tutti i test devono superare positivamente i criteri di approvazione.

?? Tutti i dati saranno raccolti in un documento da sottomettere alle autorita' di listing assieme ai fogli di calcolo, ed ai disegni delle sistemi.

Esecuzione di una serie di test sperimentali alla presenza delle autorita' di listing (UL e FM per il mercato americano).

?? Verranno scelti due sistemi da verificare fra i sistemi presentati nella documentazione.

?? Verranno ripetuti tutti i test sperimentali gia' eseguiti, ed i risultati dovranno confermare i risultati positivi gia' ottenuti.

?? Verranno richiesti dalle autorita' di listing almeno 3 nuove configurazioni di tubazioni da testare, i nuovi layout dovranno contenere:

?? I limiti di calcolo, ad esempio:

?? Minima fill density

?? Massimo tempo di scarica.

?? Massimo sbilanciamento della fine scarica degli ugelli.

?? Minimo flusso nelle tubazioni per mantenere un flusso turbolento. (halocarbons)

?? Minimo orifizio di scarica rispetto al tubo.

?? Verifica della divisione di flusso 50:50 (bull Tee).

?? Verifica della divisione di flusso 85:15 (side Tee).

?? Le tubazioni saranno dimensionate con l'utilizzo del software.

?? Si eseguiranno i test sperimentali e tutti i test ed i relativi parametri dovranno superare positivamente i criteri di approvazione.

Composizione della atmosfera del volume protetto ad estinzione avvenuta.

Thermal Decomposition Products. (Prodotti di Decomposizione Termica)

?? Tutti gli halocarbons quali: Halon 1301, HFC 227 ea, HFC 23, HFC 125 HFC 36a contatto con le fiamme ed il calore producono acido fluoridrico (HF) in quantita' dipendente dai parametri di applicazione.

?? I gas inerti quali: IG-100, IG-01, IG-55, IG-541, e CO2 non formano prodotti di decomposizione termica.

?? La quantita' di TDP dipende da:

?? Dimensioni del fuoco verso le dimensioni del volume protetto

?? Tempi di scarica dell'agente estinguente

?? Fattori di sicurezza (utilizzando una quantita' di agente superiore alla minima quantita' di spegnimento si riduce la formazione di prodotti di decomposizione termica, tempi di scarica brevi ed elevate concentrazioni di progetto riducono il tempo di contatto delle fiamme con concentrazioni di agente povere, che formano decomposizione, pertanto riducendo l'ammontare della decomposizione termica).

Il grafico di Fig 7 riporta i risultati di test eseguiti con diversi agenti estinguenti, diverse concentrazioni di progetto, dimensioni del volume diverse e specifici protocolli di test.

Il test NRC a 7.6% e 8.8% con FM 200 (HFC 227 ea) dimostra l'effetto di una concentrazione superiore di agente risultante in una minore produzione di decomposizione.

Grosse dimensioni del fuoco verso le dimensioni del volume corrispondono ad alte concentrazioni di HF ed anche a pericolose situazioni quali: ridotte concentrazioni di ossigeno, elevato sviluppo di calore, elevate concentrazioni di monossido di carbonio, etc.

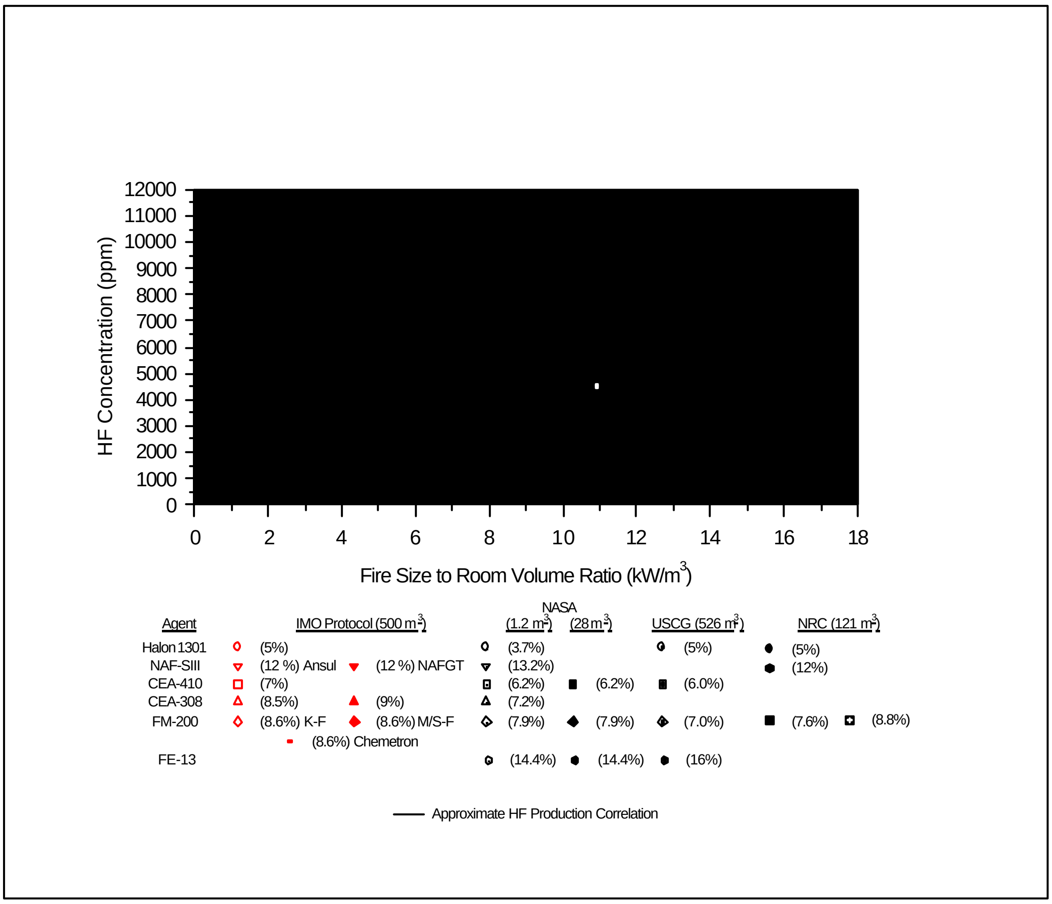


Fig 7

Rischi associati alla decomposizione termica

?? Il pericolo maggiore e' associato alla presenza di persone nel volume protetto, generalmente gli equipaggiamenti contenuti nel rischio protetto sono meno sensibili delle persone alla presenza di HF.

- ?? Il livello di pericolo per HF e' stato misurato come Dangerous Toxic Loading to Human, e rappresenta la soglia di pericolo per la salute delle persone ed e' stato valutato da Meldrum a 12.000 ppm-minuto ovvero una esposizione a 12.000 ppm di HF per 10 minuti. (1200 ppm per 10 minuti corrisponde sperimentalmente ad una dimensione di fuoco verso il volume del rischio di 2 kw/m3).

Meldrum, M., Toxicology of Substances in Relation to Major Hazards: Hydrogen Fluoride, Health and Safety Executive (HSE) Information Centre, Sheffield S37HQ, England, 1993

- ?? Una rivelazione incendio rapida ed un intervento di estinzione immediato sono i mezzi per contenere al minimo la formazione di decomposizione termica.

Il grafico di Fig 8 riporta concentrazioni di HF risultanti da test condotti su materiali e scenari tipici di industrie di elettronica e computers.

Fig 8

Permanenza dell'agente estinguente nel volume protetto

La permanenza dell'agente estinguente nel volume protetto permette il completo spegnimento del fuoco in particolare per i combustibili che formano braci, o scenari che coinvolgono elementi metallici che ancora surriscaldati potrebbero provocare la riaccensione dei combustibili, permettendo alle braci o alle superfici surriscaldate di raffreddare, mantenendo la atmosfera inerte. In particolare e' necessario prolungare il tempo di permanenza nel caso che non ci sia una interruzione automatica dell'energia elettrica.

I protocolli di test per combustibili di classe A (UL, ISO, CEN) prescrivono un tempo minimo di permanenza dell'agente estinguente nel volume protetto di 10 minuti.

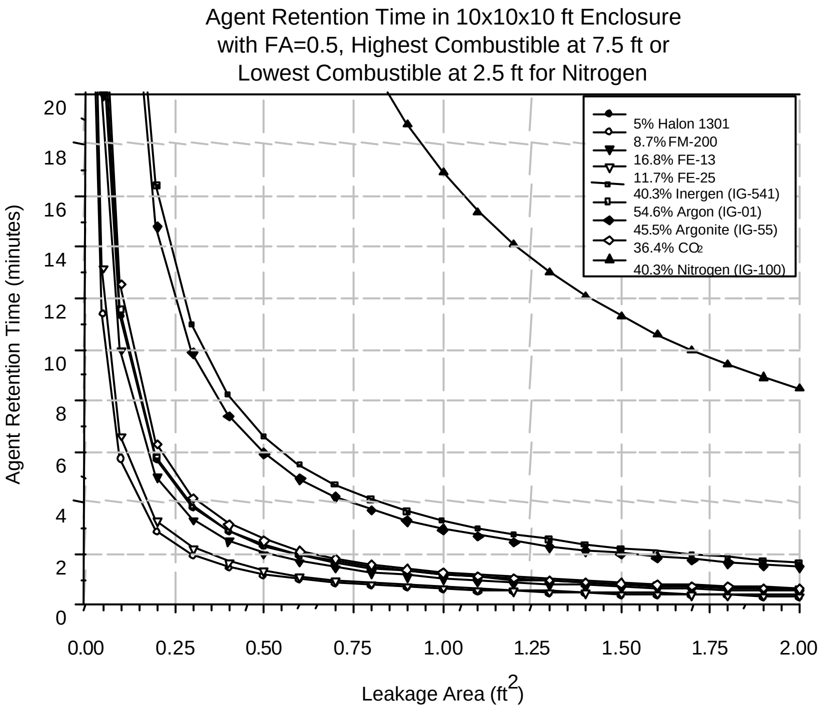


Fig 9

Gli standard prescrivono la esecuzione (prima della progettazione del sistema e periodicamente durante la sua vita operativa per verificare se ci sono stati cambiamenti dell' integrita' del volume protetto che potrebbe influire sulla efficacia della protezione) del Door Fan Integrity Test.

Questo test e' in grado di valutare l'integrita' del volume da proteggere, valutare il tempo di permanenza i ogni specifico estinguente. In funzione dei dati rilevati il progettista sara' in grado di valutare se deve applicare dei fattori di progetto aggiuntivi, o provvedere alla messa in caratteristica della integrita' del volume.

Il test si basa sulla valutazione dei parametri misurati dalla strumentazione alla luce del modello matematico che considera il fenomeno della interfaccia discendente fra l'aria in ingresso nel volume e la miscela di aria piu' estinguente ivi residente dopo la scarica. L'azoto rappresenta una eccezione poiche' la miscela aria-agente estinguente e' piu' leggera dell'aria pertanto l'interfaccia e' ascendente invece che discendente.

L'area totale di perdita e' risolta dalla seguente equazione:

Il tempo, T, per la interfaccia discendente al livello, H, nel volume e':

T = 2Aencl [(K3Hencl) 0.5-(K3H) 0.5] / K3FACDALeak

dove

K3=2g (pmix-pair) / [pmix+pair(FA/(1.0-FA))]

Normalmente si assume che alla fine del tempo di permanenza considerato la altezza della interfaccia di separazione fra aria e miscela aria-agente sia uguale o piu' superiore alla massima altezza (minima altezza per l'azoto) del materiale combustibile all'interno del volume.

Il grafico di Fig 10 riporta la comparazione del tempo di permanenza (nello stesso scenario di test) per diversi Clean Agents per concentrazioni al 30% superiore ai valori di cup burner.
Il maggior tempo di ritenzione dell'azoto e' ingannevolmente piu' favorevole in quanto molto piu' facilmente il combustibile piu' basso e' molto piu' vicino al pavimento che non il combustibile piu' alto sia vicino al soffitto.

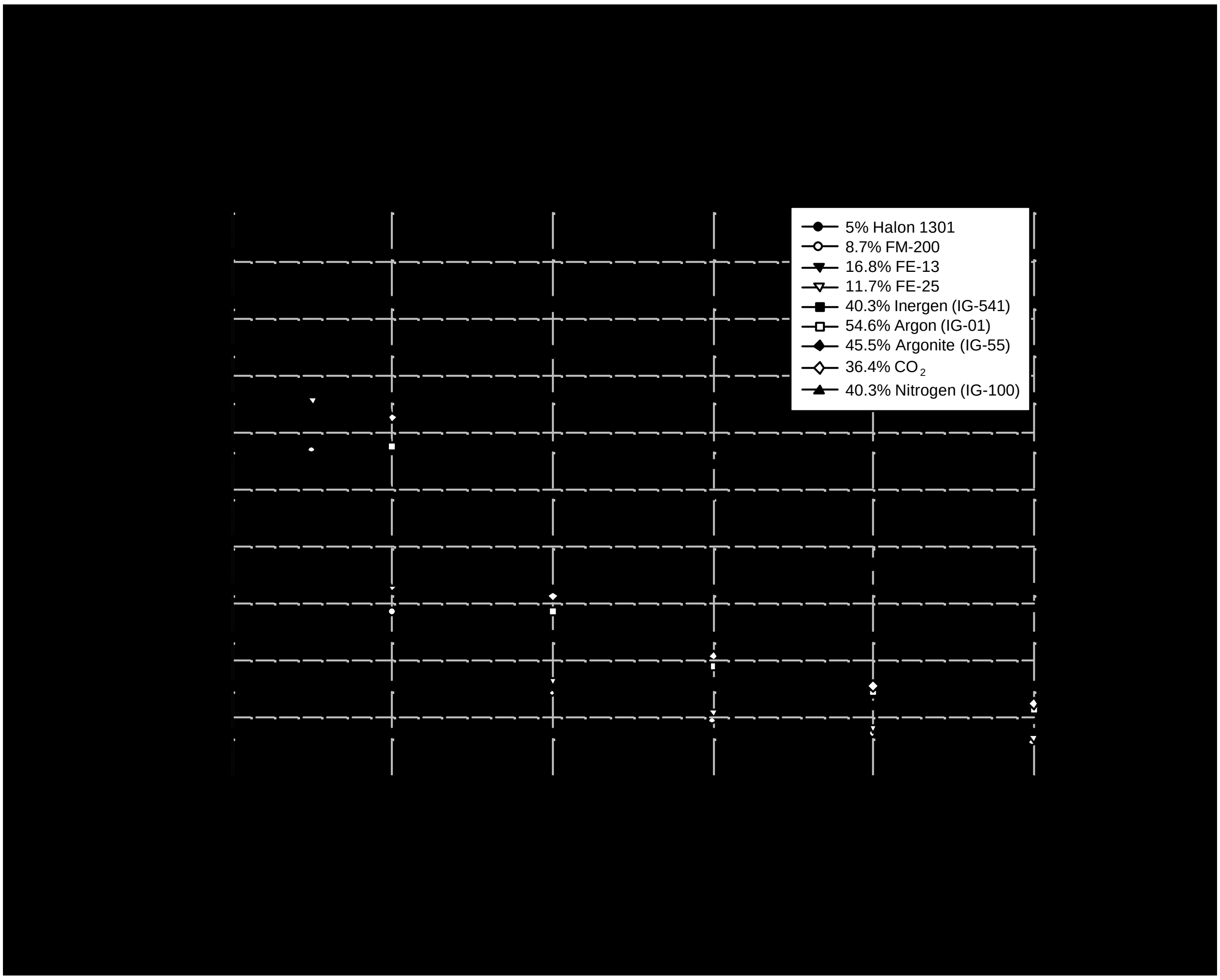


Fig 10

Pressurizzazione del volume protetto e superfici di sfogo della pressione.

La pressurizzazione del volume protetto dipende dai seguenti fattori:

?? Area totale di perdita (aperture e/o perdite del volume).

?? Concentrazioni di progetto.

?? Rateo di scarica dell'agente (tempo di scarica)

?? Per gli agenti halocarbon (gas liquefatti) come l'Halon 1301, Hfc 227 ea, HFC 23, HFC 125 HFC 36, il volume subira' due impulsi di pressione: il primo negativo dovuto alla rapida riduzione della temperatura causata dalla vaporizzazione dell'agente all'interno del volume.

?? Il secondo impulso sara' positivo, causato dal volume dell' agente aggiunto ed alla sua espansione poiche' si riscaldera', la grandezza dei due impulsi di pressione e' proporzionale al calore di vaporizzazione del'agente, piu' elevato sara' il calore di vaporizzazione piu' grande sara' la grandezza dell'' impulso di pressione negativa e inferiore sara' la grandezza dell'impulso di pressione positiva.

La applicazione di superfici di sfogo della pressione lavora in maniera antagonista al tempo di permanenza. La distribuzione delle aree di perdita e' ininfluente per la considerazione della sovrapressurizzazione del volume, e' importante che sia sufficiente indipendentemente della sua localizzazione.

Il grafico Fig 11 mostra il tipico addivenire del fenomeno per un agente halocarbon.(FM 200/HFC 227 ea).

Fig 11

Il grafico Fig 12 riporta i risultati di una serie di test condotti utilizzando l'agente estinguente HFC 227 ea (FM 200) variando le superfici di perdita del volume per diverse concentrazioni di agente, in un volume di 85 m3 (3000ft3).

Le aree di perdita utilizzate per il test corrispondono a dei tempi di ritenzione di variabili da 10 a 30 minuti.

Fig 12

Per gli agenti gas inerti (gas compressi) quali, IG -01, IG-100, IG-55, IG-541, il volume subira' un unico impulso di pressione:

?? La massima pressione del volume corrispondera' al massimo rateo di apporto dell'agente estinguente.

?? La sovrapressione generata dai gas inerti e' piu' facilmente calcolabile (rispetto agli halocarbons) poiche' la acquisizione di calore dal volume protetto e' sensibilmente ridotta.

?? Benche' nel caso dei gas inerti la sovrapressione sia piu' facile da calcolare, assume valori decisamente elevati, ponendo dei problemi di stabilita' dei volumi protetti che devono essere correttamente valutati.

Nel caso siano disponibili dettagliati calcoli di flusso e corrette informazioni dei volumi protetti, la sovrapressione puo' essere calcolata in modo affidabile con una appropriata equazione di stato.

Il grafico Fig 13 riporta l'andamento delle pressioni di un sistema calcolato con il software per i calcoli di flusso

Fig

13

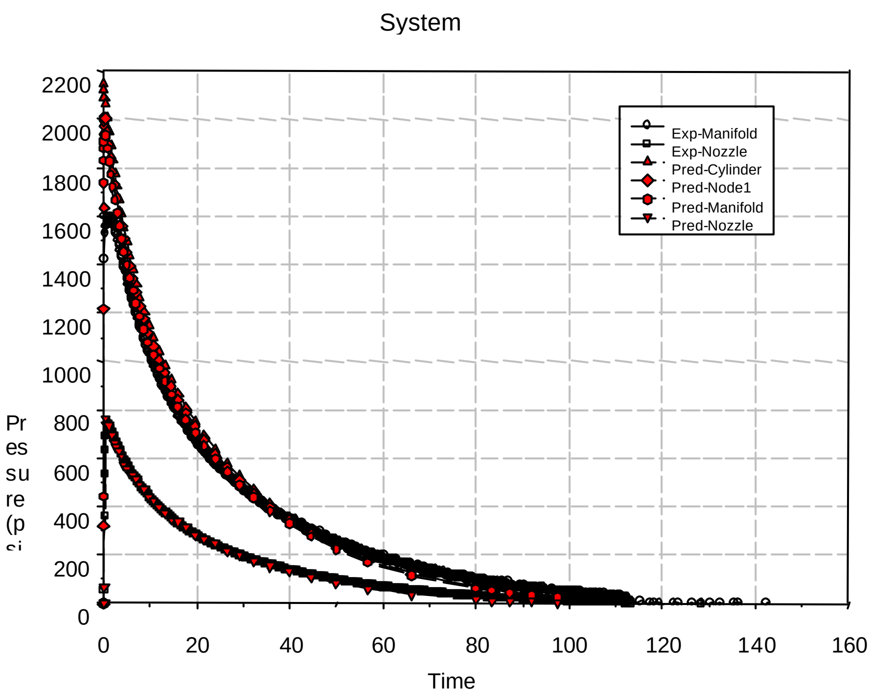


Fig 13

Il grafico Fig 14 riporta le sovrapressioni calcolate del volume protetto comparate con le sovrapressioni misurate. L'area totale di perdita e' derivata dal Enclosure Integrity Door Fan Test.

In mancanza di dettagliati ed affidabili calcoli di flusso del sistema, e' possibile calcolare la sovrapressione del volume protetto, derivandola dalla equazione dell'orifizio (area di perdita) e da una assunzione riguardante il valore di picco del flusso scaricato.

Dpencl = [Qagent,max / (CdALeak (2g/pmixg) 0.5)]2

La relazione fra il valore medio del flusso ed il valore massimo e' dipendente dalla configurazione del sistema. Generalmente si applica un fattore di correzione conservativo, risultante in una area superiore del dispositivo di evacuazione della sovrapressione.

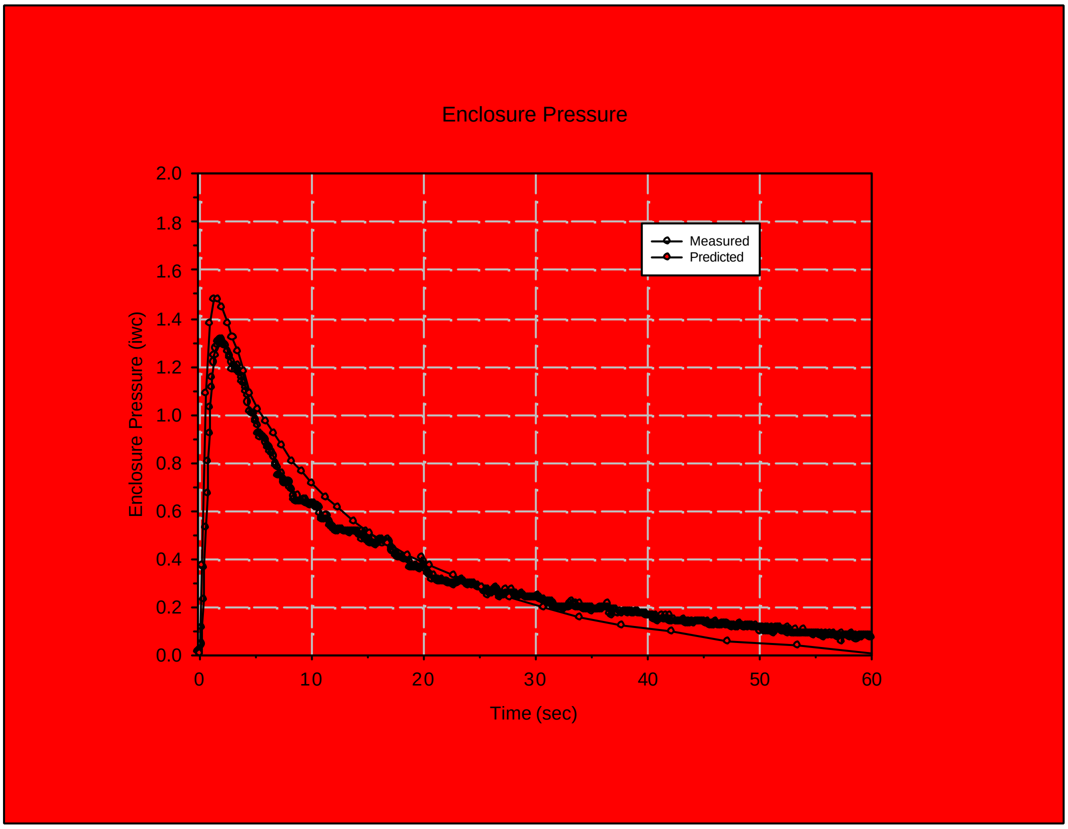


Fig 14

Resistenza del volume protetto:

?? Varia secondo il tipo di costruzione, probabilmente inferiore a quanto si possa immaginare.

?? 500 Pa puo' essere considerato un valore conservativo.

?? Sono necessari dispositivi di evacuazione delle sovrapressione nel caso che la sovrappressione risultante sia superiore al valore che ragionevolmente sia ammesso dalla resistenza della struttura o dei suoi elementi deboli.

?? Particolare attenzione deve essere fatta nella valutazione di volumi realizzati con strutture leggere o/o alluminio e vetrate.

?? Nelle applicazioni in cui si suppone uno sviluppo di fuoco modesto poiche' il sistema di estinzione e' attuato da una rivelazione incendio tempestiva e non siano presenti particolari combustibili, il contributo del fuoco allo sviluppo della sovrapressione puo' essere modesto, nel caso invece si possa supporre un potenziale sviluppo di un incendio dimensioni piu' importanti si dovra' considerare anche la contribuzione allo sviluppo della sovrapressione da parte dell' incendio.

CONSIDERAZIONI CONCLUSIVE:

?? Le concentrazioni di spegnimento sono determinate a mezzo di test, e sono specifiche per ogni agente e per ogni combustibile. E' necessario considerare la relazione fra il rischio reale ed i dati disponibili.

?? La ultima edizione dello standard NFPA 2001 include un fattore di sicurezza del 30% per i combustibili di Classe B e per i sistemi ad attuazione manuale.

?? Lo standard ISO 14520 richiede un fattore di sicurezza del 30% sia per combustibili di Classe A che B.

?? Lo standard CEN probabilmente prescrivera' alcuni accorgimenti ancora piu' cautelativi.

?? Lo standard UNI 10877 e' in corso di revisione e verra' adeguato alla ultima edizione di ISO 14520, in futuro si dovra' allineare con i requisiti dello standard CEN.

?? Per alcune protezioni il fattore di sicurezza minimo non e' sufficiente . Il progettista deve considerare tutti i parametri che possono influire sulla affidabilita' del sistema.

?? Lo standard NFPA 2001 permette di utilizzare gli halocarbons con concentrazioni superiori al NOAEL se si utilizzeranno mezzi/procedure per limitare il tempo di esposizione delle persone ai tempi derivati dalla applicazione del protocollo PBPK.

?? E' essenziale l'utilizzo di un software di calcolo affidabile e di validita' provata/certificata.

?? Un sistema di rivelazione incendi ed attuazione rapida sono i mezzi per limitare la produzione di decomposizione termica sia dell'agente estinguente che da parte dell'incendio. Questa situazione deve essere particolarmente valutata quando sia richiesta una azione di estinzione rapida, quindi vanno considerati i tempi di erogazione degli estinguenti. (10 secondi per halocarbons, 1 minuto o piu' per i gas inerti ed l'anidride carbonica).

?? Il tempo di permanenza dell'agente estinguente all'interno del volume protetto dipende dalla concentrazione (quantita') di agente, dell'area totale di perdita, e dalla ubicazione delle perdite.

?? Non esiste una prescrizione di quanto deve essere protratto il tempo di permanenza dell'agente estinguente, il progettista dovra' valutare il rischio e considerare la possibilita' di sorgenti di ignizione persistenti dopo la scarica, quanto tempo sara' necessario per permettere l'estinzione delle braci, ed il tempo necessario poiche' le superfici surriscaldate si raffreddino.

?? Le sovrappressioni sviluppate all'interno dei volumi protetti dipendono dal tipo di agente estinguente, la con concentrazione di progetto, l'area di perdita, ed il tempo di scarica.

?? Se la sovrapressione eccede la resistenza delle strutture e componenti del volume protetto si dovranno istallare dei dispositivi di evacuazione della sovrapressione.

SIMULAZIONE DI INCENDIO IN EDIFICIO CIVILE CON PRESENZA DI PUBBLICO MEDIANTE MODELLO CFD
FDS3 Applicato allo Studio dell'Andamento dei Fumi

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1 SINTESI DELLO STUDIO

Lo studio consiste nell'analisi di uno scenario di incendio in un edificio civile destinato ad accogliere pubblico, in corso di ristrutturazione ma sottoposto a vincoli di natura architettonico/strutturale, mediante l'applicazione di un modello CFD di simulazione di incendio. Lo scopo dello studio è quello di prevedere l'andamento dei fumi prodotti da un incendio campione determinato in base ai materiali combustibili presenti o verosimilmente prevedibili, in un volume determinato in base alle caratteristiche di compartimentazione dell'edificio ed in tempi confrontabili con quelli attesi per il pieno sviluppo di eventi di questo tipo. La zona oggetto della simulazione comprende il piano terra dell'edificio, le due scale che su di esso si affacciano ed il loggiato dove è previsto sfocino i fumi, al fine di valutare l'agibilità dei percorsi di esodo che comprendono le due scale già menzionate in relazione alle condizioni di visibilità e di concentrazione dei prodotti di combustione dovuti all'incendio. L'attività descritta è stata condotta applicando il modello di fluidodinamica computazionale FDS (versione 3) sviluppato dal NIST.
È stata analizzata l'agibilità dei percorsi di esodo descritti, per i quali la simulazione prevede condizioni di visibilità e di concentrazione di prodotti di combustione che non ne pregiudicano l'uso nei tempi necessari all'evacuazione, tenendo conto degli impianti di estrazione fumi e ventilazione di emergenza previsti a progetto. E' stato inoltre considerato il caso in cui non sia in funzione il sistema di estrazione fumi e di ventilazione delle scale.

2 QUALIFICHE PROFESSIONALI

La società Industrial Loss Control & Engineering opera ormai da circa 20 anni nel settore della prevenzione dei danni, in qualità di società di servizio per le Aziende Industriali più varie, con settori di produzione che vanno dalla chimica al vetro, dagli alimentari ai trasporti, fino alle aziende che operano a loro volta nel campo dei servizi d'ingegneria e che si avvalgono di specialisti in aree specifiche.
Da oltre tre anni la ILC&e. ha avviato una partnership operativa con Hughes Associates Inc., società statunitense leader nell'ingegneria e nella ricerca applicata nel settore della prevenzione e protezione contro gli incendi.
Hughes Associates ha applicato modelli di simulazione a molteplici scenari di incendio, utilizzando FDS sin dalle fasi iniziali dello sviluppo del modello.
ILC ha condotto e sta tuttora svolgendo una serie di studi in collaborazione con i Laboratori del Gran Sasso dell'Istituto Nazionale di Fisica Nucleare, analizzando scenari di incendio come:

- incendio catastrofico in galleria autostradale ([1]: *CFD Simulations of a Truck Fire in the Underground Gran Sasso National Laboratory*);
- incendio di auto in galleria con protezione water mist;
- incendi e propagazione di fumi con coinvolgimento di cavi di segnale e potenza, di rack elettronici.

3 METODO

Il metodo utilizzato nello sviluppo dello studio di sicurezza oggetto di questa relazione è consistito nell'applicazione dei criteri di analisi prestazionale antincendio internazionalmente riconosciuti come rispondenti allo stato dell'arte ([2]: *SFPE Engineering Guide to Performance-Based Fire Protection Analysis and Design of Buildings*).

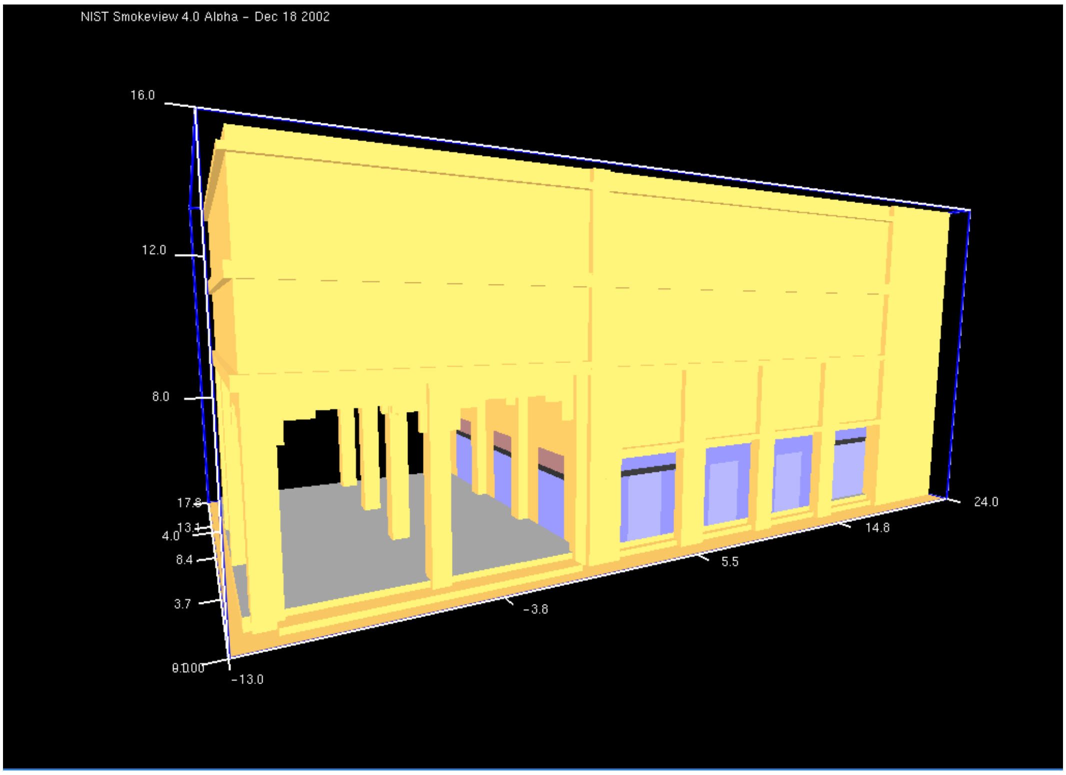

Figura 1. Dominio di simulazione.

In particolare l'approccio è consistito nella determinazione delle fasi per mezzo delle quali condurre l'analisi di tipo prestazionale, partendo dalla definizione della portata del progetto, attraverso l'identificazione dello scopo e degli obiettivi fino allo sviluppo dello scenario di incendio e alla analisi dei risultati previsti dalla simulazione.

4 SCOPO ED OBIETTIVI

Lo scopo dello studio è quello di prevedere l'andamento dei fumi prodotti da un incendio campione, definito in base alla quantità ed alla tipologia di materiale combustibile presente nel compartimento considerato, in un volume predefinito e in tempi confrontabili con quelli attesi per il pieno sviluppo di eventi di questo tipo.
La zona oggetto della simulazione è un'ampia porzione dell'edificio - ex cinema collocato nel centro storico - che comprende il vano corrispondente a due delle quattro scale a servizio dell'edificio ed il piano terra. La piccola libreria posta al piano terra è caratterizzata dalla moderata presenza di materiale combustibile di natura editoriale (libri, opuscoli di promozione turistica).
Lo studio dell'andamento dei fumi e dei prodotti di combustione a seguito di un incendio localizzato nella libreria è stato condotto al fine di valutare l'agibilità delle vie di esodo che comprendendo le scale e la zona prospiciente la libreria stessa.
L'attività descritta è stata condotta applicando il modello di fluidodinamica computazionale FDS (versione 3) sviluppato dal NIST ([3],[4],[5] McGrattan et al., 2001; [6]).

4.1 *Criterio prestazionale*

Una volta determinato il tempo di evacuazione complessivo ed esaminata la distribuzione dei fumi e dei prodotti di combustione all'istante di completa evacuazione[AF1], è stata valutata la concentrazione di fumi, ossigeno, monossido di carbonio ed anidride carbonica a 2 metri di altezza ([10] Drysdale D., 1998, p. 394) al piano terra, intermedio, primo e secondo. Al fine di valutare l'adeguatezza dei percorsi di esodo, è stato individuato come criterio di accettabilità l'insieme di valori di soglia elencati in Tabella 1.

Tabella 1. Criterio prestazionale: soglie di accettabilità per visibilità e concentrazione di prodotti di combustione

Soglie di accettabilità per visibilità e concentrazione di prodotti di combustione		
Specie	*Soglia di accettabilità*	*Descrizione*
Visibilità	9 m	Visibilità per oggetti illuminati da fonti esterne, corrispondente a circa 25 m per sorgenti luminose (si noti che la larghezza del piano terra è 16.8 m)
Ossigeno	15 %	Primi segni di affaticamento
Monossido di carbonio	80 ppm	Primi segni di affaticamento (4000 ppm sono letali in meno di un'ora)
Anidride carbonica	0.5 %	Limite di sicurezza per esposizione prolungata (la concentrazione del 3 % induce il raddoppio della frequenza respiratoria)
Temperatura	50 °C	In condizioni di umidità relativa inferiore al 50% corrisponde ad un tempo di tollerabilità di 2 ore

5 IL MODELLO: FDS

Fire Dynamics Simulator (FDS) è un modello sviluppato dal NIST che simula l'incendio e ne predice gli effetti, cui è associato Smokeview, un post-processore grafico che può essere utilizzato per analizzare i dati prodotti da FDS.
FDS risolve una forma delle equazioni di Navier-Stokes appropriata per i flussi termici a bassa velocità di fumi e gas generati in un incendio. FDS è stato oggetto di numerosi studi di validazione sia interni al NIST sia di enti esterni.
FDS permette la modellazione dell'incendio a partire da un database di materiali standard, distribuito con il programma, consentendo al tempo stesso all'utente l'introduzione di nuovi materiali definiti in base alle relative caratteristiche chimico-fisiche ed ai dati di incendio sperimentali. La dinamica dell'incendio è poi simulata in base ai parametri che caratterizzano ciascun materiale presente nel dominio di simulazione, ciascuno con le proprie caratteristiche di infiammabilità e combustione o di reazione all'incendio. Infatti, in base a questi dati, FDS risolve numericamente (con un metodo ai volumi finiti) le equazioni che modellano la reazione di combustione ed i fenomeni di trasporto, tenendo conto dinamicamente delle mutue interazioni tra i processi.
FDS è in grado di calcolare e conseguentemente fornire come dati di uscita, previo un opportuno set-up della simulazione in modo che le quantità di interesse vengano effettivamente calcolate, i valori di tutte le variabili, scalari e vettoriali, calcolate in ciascuna delle celle del dominio, utili alla comprensione dei fenomeni ed alla analisi degli effetti (concentrazioni delle specie chimiche, distribuzioni delle temperature / pressioni / velocità dei gas / fumi, visibilità, …).

6 SCENARIO DI INCENDIO E FOCOLAIO CAMPIONE

6.1 *Studio preliminare dei materiali combustibili presenti*

È stata condotta una analisi al fine di valutare la presenza di materiale combustibile nell'area oggetto dello studio.
La zona in questione si presenta caratterizzata da una generale ridotta presenza di materiale combustibile, ad eccezione di quanto descritto nel seguito.
È stato possibile identificare il maggiore carico di incendio come quello costituito dalla presenza di libri ed opuscoli in esposizione destinata alla vendita.
Dalle informazioni raccolte e da considerazioni sul ridotto spazio dedicato alla libreria, è stato individuato il quantitativo corrispondente a circa 1.5 m^3 di libri, ipotizzati disposti per un metro in altezza su un'area pari a 1.5 m^2.

6.2 *Definizione e set-up dello scenario di incendio*

6.2.1 Definizione e set-up del fuoco campione

6.2.1.1 Reazione chimica

Avendo determinato la tipologia del materiale presente in prevalenza, è stato possibile definire la reazione chimica di combustione da utilizzare nel modello, in modo tale da prevedere la quantità di fumi prodotta dall'incendio ed il loro andamento spazio-temporale nel modo più accurato. A tal fine è stata utilizzata la reazione "WOOD" contenuta nel database standard di FDS, modificata in modo da tener conto degli opportuni valori di resa di fumo e di CO[AF2].

6.2.1.2 Incendio campione

Per quanto riguarda la modellazione del tipo di incendio, dai dati sperimentali disponibili in letteratura a proposito di incendi di tipologie di materiale simili a quelli oggetto della simulazione ([11] Quintiere, 1998, p.125; [10] Drysdale D., 1998, p. 324), è stato ipotizzato un incendio di andamento t^2 di tipo "medium/slow", con tempo caratteristico 480 s.

6.2.2 Definizione e set-up del dominio geometrico della simulazione

Lo studio preliminare ha permesso di raccogliere le informazioni necessarie a caratterizzare la geometria dell'edificio, del suo contenuto e dei materiali strutturali. Il dominio della simulazione è costituito da una porzione di fabbricato di ampiezza pari a circa 37 m, larghezza 18.8; l'altezza del dominio di simulazione è pari a 16 m.

FDS consente di descrivere il dominio di simulazione mediante una griglia tridimensionale di celle a forma di parallelepipedo. Tutti i particolari geometrici sono descrivibili lasciando le celle vuote o mediante l'introduzione di ostruzioni che vadano ad occupare una o più celle.

Il dominio di simulazione è stato suddiviso in 622'080 celle (144 per 72 per 60) di circa 0.25 m di lato: di conseguenza tutti i particolari geometrici sono rappresentabili con una risoluzione di circa 0.25 m.

Dalle immagini è possibile notare come gli elementi strutturali, siano stati inseriti nel modello perché essenziali al fine di ottenere un andamento dei fumi verosimilmente rispondente alla realtà. Inoltre, al fine di non sottostimare la velocità di stratificazione e di discesa dei fumi nell'ambiente, sono stati inclusi nella definizione del dominio geometrico i principali ingombri che, nello scopo e nei tempi della simulazione, possono essere considerati volumi non permeabili ai fumi: controsoffitto, scaffali, arredi, ...

Sono state altresì incluse nella simulazione 3 sistemi di estrazione fumi verso il loggiato, ciascuno in grado di espellere la portata di 4 m^3/s ed il sistema di ventilazione di emergenza delle scale, con 6 bocche di immissione da 1 m^3/s ciascuna.

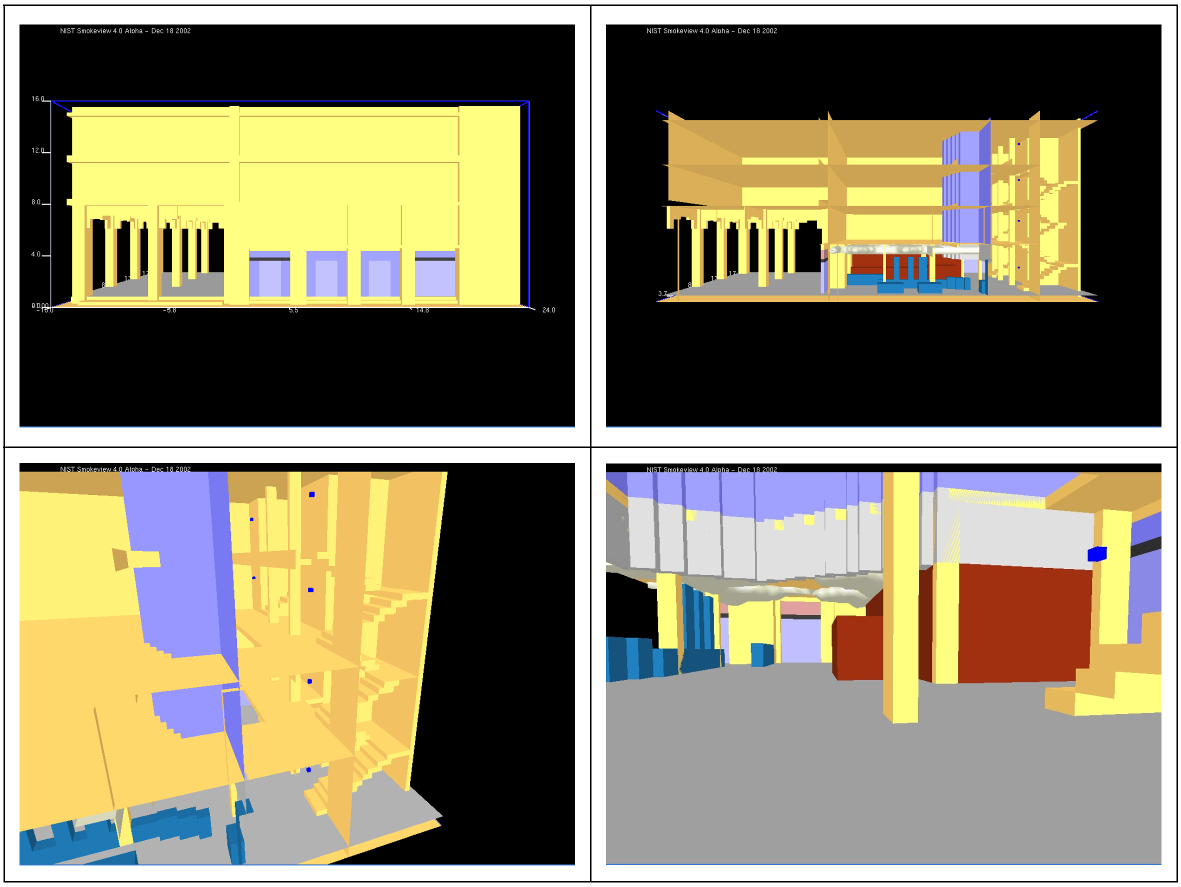

Figura 2. Particolari del dominio di simulazione.

6.3 *Verifica dei parametri di simulazione e del modello di fuoco campione*

La descrizione geometrica del dominio di simulazione è stata verificata mediante esecuzione di alcuni *run* di test del programma di simulazione e l'analisi grafica dei risultati con Smokeview (si veda il par. 5).

6.4 *Esecuzione e verifica della simulazione di incendio*

Una volta definito il dominio geometrico ed il modello di incendio, sono stati eseguiti alcuni *run* di verifica dell'assetto della simulazione, al fine di evidenziare eventuali comportamenti difformi da quanto atteso in base alla teoria della dinamica dell'incendio, senza peraltro riscontrare anomalie.
Inoltre è stato necessario definire il tipo e le modalità di produzione e di visualizzazione dei dati prodotti dalla simulazione, scegliendo di produrre risultati sia sotto forma di tabelle con i parametri numerici di interesse, sia di immagini di più immediata interpretazione.

7 ANALISI DELLE PREVISIONI DEL MODELLO

7.1 *Fasi temporali dello sviluppo dell'incendio in relazione all'esodo*

7.1.1 Ignizione

Per quanto riguarda la simulazione, la fase di innesco dell'incendio non è molto significativa in quanto il processo di ignizione può essere immaginato con tempi e rampe di innesco differenti, ma si può ritenere che sostanzialmente lo sviluppo dell'incendio dal momento dell'accensione (sempre supposta con sorgente di limitata entità) segua il medesimo andamento.

7.1.2 Rivelazione dell'incendio

Nella zona oggetto della simulazione è presente l'impianto automatico di rivelazione di incendio. La rivelazione precoce di incendio consente di assumere, in relazione al tipo di incendio ipotizzato, che l'istante di rivelazione dell'incendio $t_{rivelazione\,incendio}$ sia al più dello stesso ordine di grandezza del tempo in cui l'incendio, esaurito il transitorio, raggiunge il suo pieno sviluppo (330 s)[AF3]. Poniamo quindi:

$$t_{rivelazione\,incendio} = 300\,\mathrm{s} \qquad (1)$$

Nella scala di tempi della simulazione l'istante iniziale coincide con l'istante di accensione t_0:

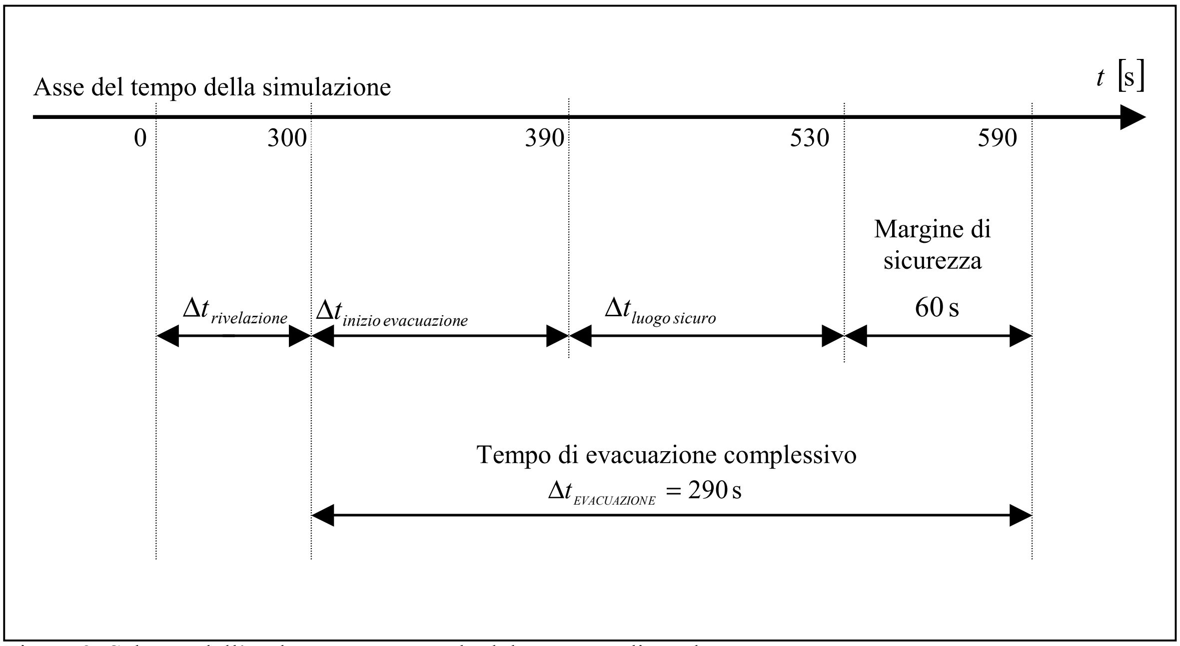

Figura 3. Schema dell'andamento temporale del processo di esodo.

$$t_0 = 0\,\text{s} \tag{2}$$

7.1.3 Inizio del processo di evacuazione

È noto ([13] SFPE Handbook, 1995, sec. 3 chap. 14; [14] Vigne G., Marsella S., 2000) che tra l'istante di rivelazione dell'incendio ed il momento in cui il processo di evacuazione ha effettivamente inizio può intercorrere un ritardo che, dipendendo da molteplici fattori, può essere in generale stimabile in 60÷120 secondi. Per quanto riguarda l'oggetto dello studio, l'intervallo di inizio evacuazione è stato ritenuto pari a 1.5 minuti; di conseguenza è possibile indicare:

$$\Delta t_{inizio\ evacuazione} = 90\,\text{s} \tag{3}$$

7.1.4 Completa evacuazione

Il percorso di esodo più sfavorito è di lunghezza circa pari a 60÷70 m. Assumendo in modo cautelativo che la velocità di spostamento sia pari a 0.5 m/s - valore inferiore alla metà del valore di velocità di esodo tipicamente accettato in letteratura per condizioni normali - è possibile determinare il tempo $\Delta t_{luogo\ sicuro}$ necessario per raggiungere un luogo sicuro a partire dalla posizione più sfavorita:

$$\Delta t_{luogo\ sicuro} = 140\,\text{s} \tag{4}$$

7.1.5 Tempo di evacuazione complessivo

In base alle considerazioni svolte nei paragrafi precedenti, è possibile riassumere schematicamente l'andamento temporale del processo di esodo, avendo incluso un ulteriore margine di sicurezza pari a 60 secondi ([15] La Malfa A., 2001):
È immediato ricavare che il tempo di evacuazione complessivo, considerato a partire dall'istante in cui l'incendio viene rivelato, può essere così determinato:

$$\Delta t_{EVACUAZIONE} = \Delta t_{inizio\ evacuazione} + \Delta t_{luogo\ sicuro} + \text{margine di sicurezza} = 90\text{s} + 140\text{s} + 60\text{s} = 290\text{s} \tag{5}$$

È opportuno chiarire che il margine di sicurezza qui introdotto non preclude che, come si vedrà nel seguito, al di là di quel tempo le condizioni di sicurezza si protraggano comunque, anche se ciò non è richiesto ai fini di questo studio.

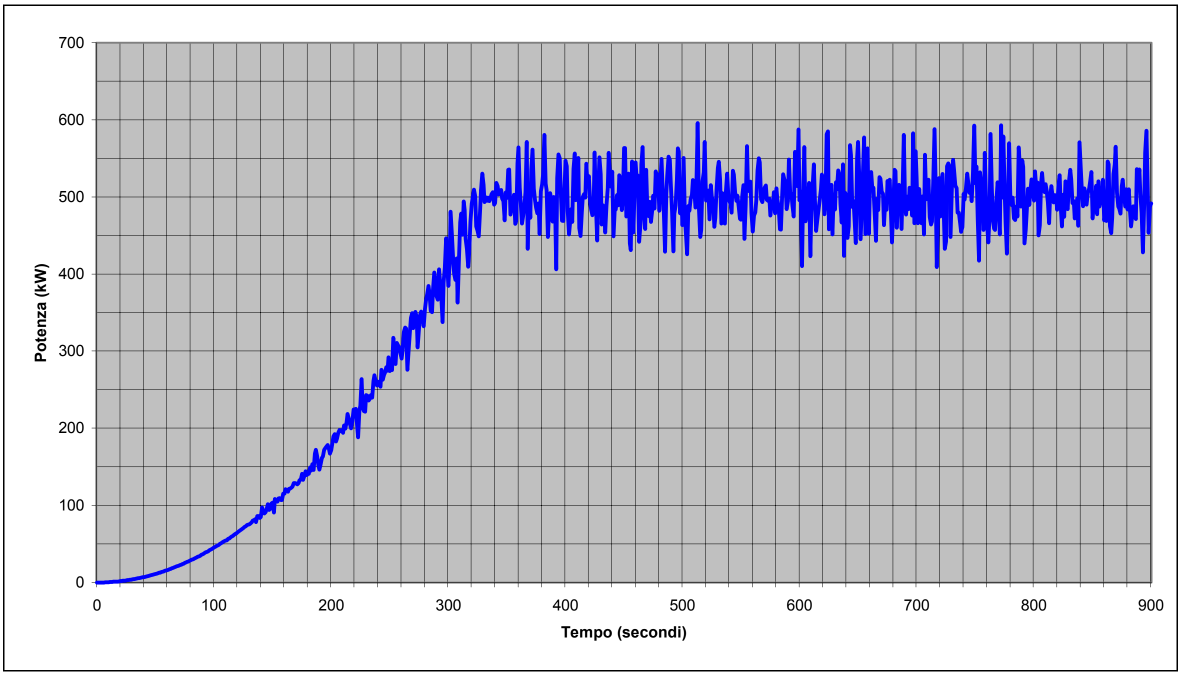

Figura 4. Andamento temporale della potenza rilasciata dall'incendio.

7.2 *Potenza rilasciata*

7.2.1 Andamento temporale della potenza rilasciata

Nel grafico riportato in Figura 4 è possibile valutare l'andamento temporale della potenza rilasciata dall'incendio simulato, in cui l'incendio mostra il tipico andamento parabolico crescente sino al valore di circa 0.5 MW mantenuto a regime.

8 VALUTAZIONE DELLA RISPONDENZA AI CRITERI PRESTAZIONALI

8.1 *Concentrazione di fumi e condizioni di visibilità al tempo di completa evacuazione*

Nelle immagini di Figura 5 e Figura 6 sono mostrate le superfici al di fuori delle quali la visibilità è superiore rispettivamente a circa 10 e 20 metri, all'istante di completa evacuazione.
Nella Tabella 2 è possibile valutare le concentrazioni di fumo e dei prodotti di combustione relative ai punti descritti al par. 4.1. I valori riportati sono riferiti alla posiziona più sfavorevoli, al piano terra ed al secondo piano. La Figura 7 mostra l'andamento temporale della visibilità nei punti di misura ad altezza uomo (2 m) ai piani terra, ammezzato, primo e secondo (si veda anche la Figura 2 ove sono evidenziati i punti di misura).

Tabella 2. Condizioni di visibilità, di concentrazione di ossigeno, fumo e prodotti di combustione lungo le vie di esodo al piano terra; l'istante di completa evacuazione è in grassetto

Visibilità e concentrazione dei prodotti di combustione						
Tempo (s)	Particolato (mg/m^3)	Visibilità (m)	O_2 (%)	CO (ppm)	CO_2 (%)	Temperatura (°C)
240	0.17	30.00	20.72	0.04	~0	20.04
480	14.18	27.83	20.61	3.28	0.09	22.52
590	**13.58**	**29.06**	**20.62**	**3.14**	**0.08**	**22.19**
720	22.82	17.30	20.54	5.30	0.14	23.91
960	11.28	30.00	20.63	2.60	0.07	21.57

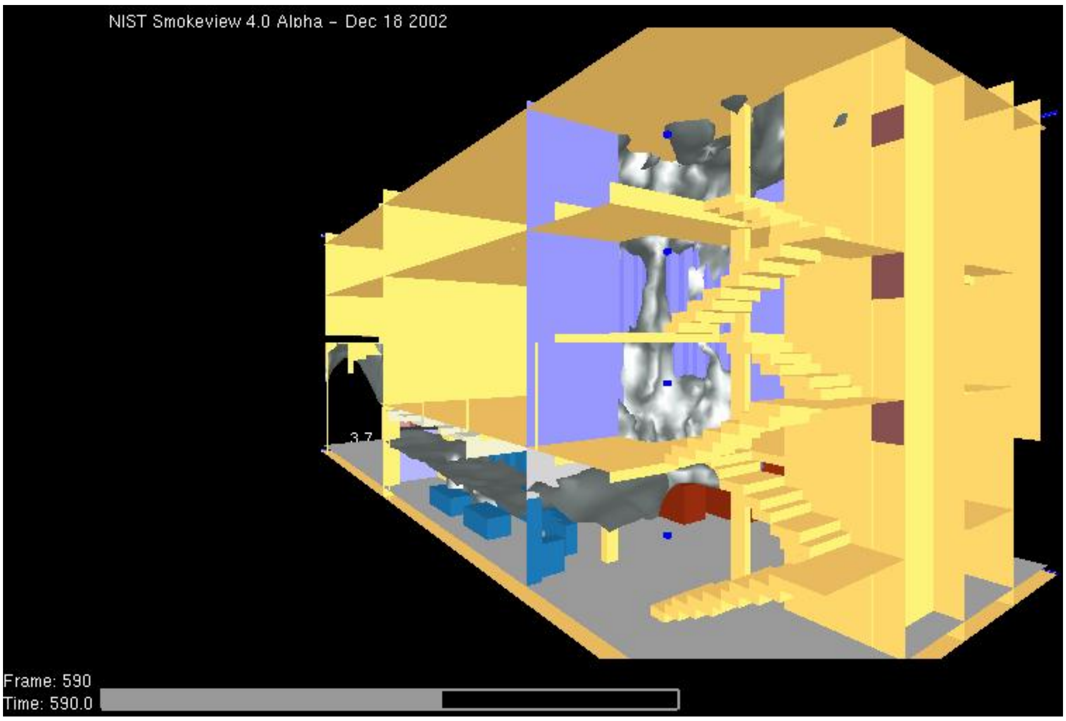

Figura 5. Istante di completa evacuazione: inviluppo dei fumi che determinano visibilità inferiore a 10.42 m

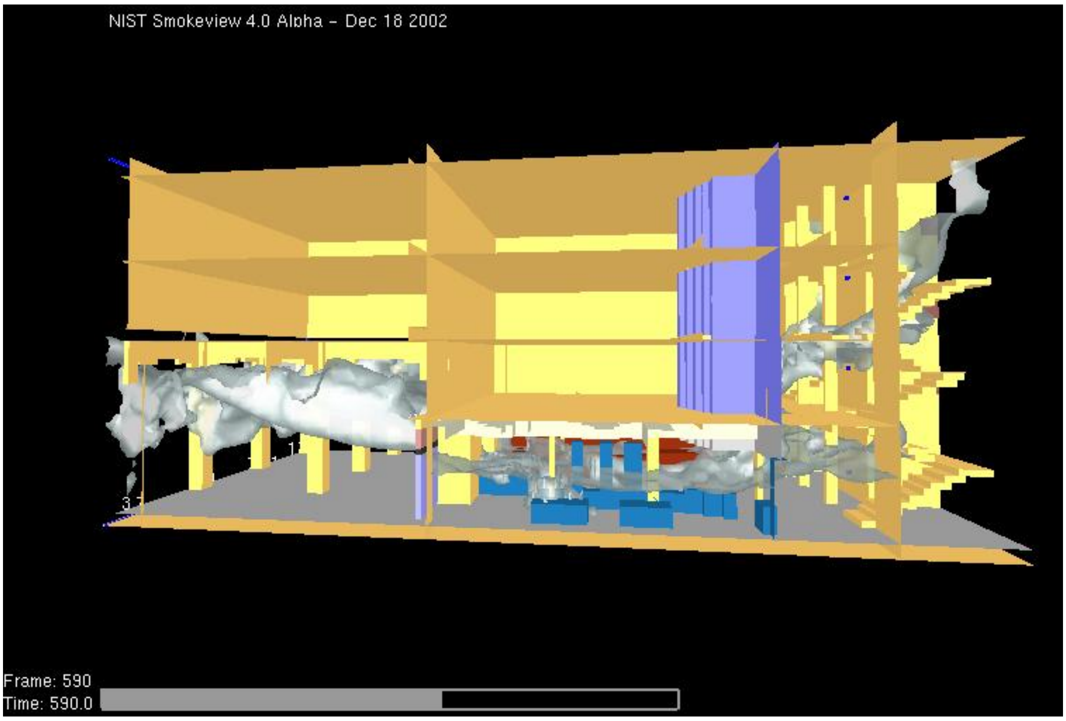

Figura 6. Istante di completa evacuazione: inviluppo dei fumi che determinano visibilità inferiore a 20.82 m

La visibilità, ovvero la capacità di vedere oggetti attraverso il fumo, può essere ricavata conoscendo concentrazione e caratteristiche di opacità del fumo.
Come è noto ([11] Quintiere, 1998, p.162; [10] Drysdale D., 1998, p. 381), l'intensità della luce monocromatica che attraversa la distanza L nel fumo è attenuata secondo la legge:

$$\frac{I}{I_0} = e^{-K/L} \qquad (6)$$

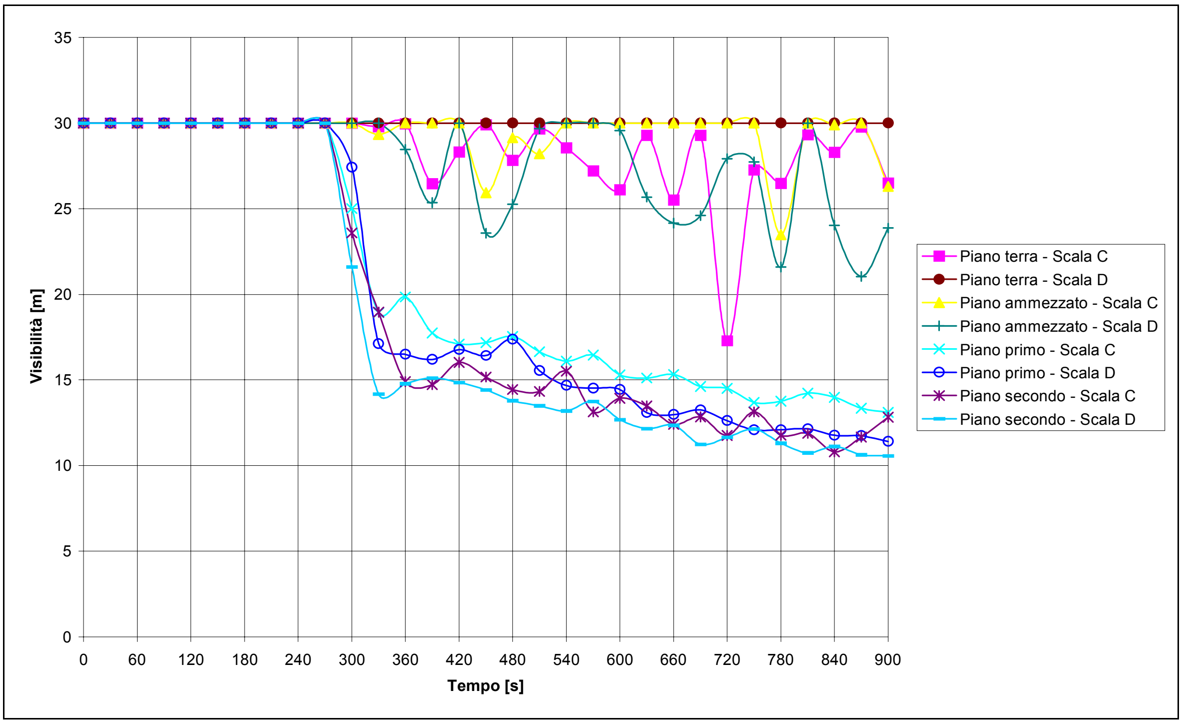

Figura 7. Visibilità ad altezza uomo (2 m) in prossimità delle scale ai piani: terra, ammezzato, primo e secondo

Tabella 3. Condizioni di visibilità, di concentrazione di ossigeno, fumo e prodotti di combustione lungo le vie di esodo al piano secondo; l'istante di completa evacuazione è in grassetto

Visibilità e concentrazione dei prodotti di combustione						
Tempo (s)	Particolato (mg/m^3)	Visibilità (m)	O_2 (%)	CO (ppm)	CO_2 (%)	Temperatura (°C)
240	4.47	30.00	20.69	1.03	0.03	21.07
480	28.63	13.79	20.50	6.67	0.18	24.81
590	**32.53**	**12.13**	**20.47**	**7.57**	**0.20**	**24.66**
720	33.88	11.65	20.46	7.88	0.21	24.41
960	39.33	10.04	20.41	9.16	0.24	24.93

Il coefficiente di assorbimento K è ricavabile da un coefficiente di assorbimento riferito all'unita di massa K_m caratteristico del combustibile e dalla densità del fumo, calcolata dalla simulazione. È stato utilizzato il valore K_m=7600 m^2/kg, valore opportuno per combustione con fiamma di legno e plastica ([4] McGrattan et al., 2001, p. 51).
La visibilità di un oggetto dipende inoltre dal tipo di illuminazione cui è sottoposto: nella simulazione, in via conservativa, si sono considerate le condizioni di visibilità riferite ad oggetti illuminati da fonti esterne.

8.2 *Verifica del criterio prestazionale*

In base a quanto indicato al paragrafo 4 ed ai risultati indicati nei paragrafi precedenti, è possibile affermare che all'istante di completa evacuazione le condizioni di visibilità e di concentrazione di prodotti di combustione siano tali da non pregiudicare l'uso dei percorsi di esodo considerati.

9 SIMULAZIONE IN ASSENZA DEI SISTEMI DI ESTRAZIONE FUMI E VENTILAZIONE

La medesima simulazione sin qui descritta è stata poi condotta ipotizzando che i sistemi di estrazione fumi e di ventilazione delle scale non siano attivi. I risultati, riferiti al secondo piano - zona più sfavorita, sono raccolti nella tabella seguente e mostrano che le condizioni all'istante di completa evacuazione sono compatibili con l'uscita degli occupanti lungo i percorsi di esodo considerati, fatta salva la visibilità che risulta a tratti significativamente ridotta.

Tabella 4. Condizioni di visibilità, di concentrazione di ossigeno, fumo e prodotti di combustione lungo le vie di esodo al secondo piano, nella ipotesi sistemi di estrazione fumi e ventilazione di emergenza non attivi.

Visibilità e concentrazione di prodotti di combustione						
Tempo (s)	Particolato (mg/m^3)	Visibilità (m)	O_2 (%)	CO (ppm)	CO_2 (%)	Temperatura (°C)
240	6.45	30.00	20.67	1.67	0.04	21.82
480	60.10	5.79	20.18	16.25	0.43	32.13
590	**103.89**	**3.80**	**19.88**	**25.01**	**0.66**	**34.92**
720	151.98	2.60	19.48	37.01	0.98	38.47
960	214.95	1.84	18.97	52.28	1.38	38.09

10 CONSIDERAZIONI AGGIUNTIVE

Come già indicato, alcune considerazioni sviluppate durante lo studio si basano su ipotesi e presupposti che vengono qui di seguito riassunti.

10.1 *Materiali combustibili*

In base alle caratteristiche dei materiali presenti, nello scopo e negli obiettivi del presente studio, si è assunto che i materiali e le apparecchiature circostanti non partecipino all'incendio, almeno entro i limiti temporali investigati dalla simulazione effettuata (15 minuti).

10.2*Prodotti di combustione*

Sempre nei limiti dello scopo e degli obiettivi del presente studio, non sono stati analizzati l'irraggiamento e le concentrazioni di prodotti di combustione al di fuori di fumo, CO e CO_2. D'altro canto, nelle condizioni descritte, la visibilità dovuta al fumo può essere considerata il primo effetto in un incendio, ancor prima che l'incendio causi rischi di natura termica ([11] Quintiere, 1998, p.162).

11 CONCLUSIONI

È stato descritto uno studio di simulazione di incendio presso un edificio civile destinato ad accogliere pubblico, in corso di ristrutturazione ma sottoposto a vincoli di natura architettonico/strutturale. L'analisi è stata svolta applicando la versione 3 di FDS, modello CFD sviluppato dal NIST. Lo studio ha lo scopo di prevedere la diffusione di fumi e prodotti di combustione dovuta ad un incendio campione, con l'obiettivo di valutarne la concentrazione lungo le vie di esodo che ne possano essere esposte.
La simulazione ha previsto che le condizioni di visibilità e di concentrazione di prodotti di combustione non ne pregiudicano l'uso nei tempi necessari all'evacuazione.

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RESTORATION AND FIRE PROTECTION OF THE PICCINNI THEATER IN BARI: CONTROLLED VENTILATION TO EXHAUST SMOKE AND CONTAIN FIRE

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ABSTRACT

Smoke production and spread during a fire has been for years a subject not fully investigated and considered within fire protection design activities. Only recently, as a consequence of a better understanding of phenomena obtained through fire modelers, it is growing awareness and knowledge on this theme and it begins to be appreciable its influence on design solutions.

Even though fire modelers algorithms and procedures can be considered quite consolidated by more then a decade of studies and applications, there still remains a relevant need of validation by means of real tests that could confirm models results with respect to specific phenomena.

Among these the one presented in this paper concerning the influence of forced ventilation, with respect to natural one, on fires in compartments with a relevant presence of burning materials. Through forced ventilation, according to model results, it seems to be possible to produce a kind of fire control reducing fire sizes, temperatures and consequent damages. Beside a general interest in all cases characterized by a relevant presence of burning materials, this can influence fire protection designs concerning historical buildings, wooden structured ones, compartments containing materials to be fire protected. Not secondary seems to be too, especially for public premises with relevant presence of people, the effect obtained, through forced ventilation and as showed by the modeler, with respect to better inner conditions in case of fire.

Keywords

performance based design - controlled ventilation - smoke control - fire modelers

INTRODUCTION

Fire protection design of buildings, characterized by the presence of a relevant number of people and/or quantity of burning materials, is a quite complex task that has to be accomplished considering numerous and interrelated aspects. While it has to be assured the possibility for people to leave, rapidly and in safety, rooms interested by the fire, it has not to be disregarded to determine safety conditions for rescue teams intervention. Maintaining these priorities, it should not be disregarded to realize conditions that could permit to save the building and its content.

Efficiency of escape routes, fire behavior of materials, structural fire resistance are the themes that have been considered, for years, as those to take care of or, at least, the main ones. Only more recently smoke production and spread have gained general interest even though it can be said that they still remain subjects needing to be still further investigated and, consequently, considered within Fire Codes and Regulations. The situation differs variously from Country to Country. Where more advanced are studies and awareness for fire risks, materials begin to be classified too according to their gas emissions in case of fire and there is an increasing interest and research effort with reference to simulation models able to perform a detailed description of different "scenarios" developing during a fire. ?1? ?2?

In Europe gas emissions of materials are still under consideration by technical committees. The aim is to define common tests to be adopted in the different Countries. Within European Fire Codes and Regulations the smoke subject is relatively present even if more as a general theme than a specific one really regulated or studied. What can be usually found is a generic reference to systems to remove smoke and, mainly, by means of natural vents to be activated and normally located in the ceilings. Somewhere can be found references to alternatives represented by natural or mechanical systems (i.e. in France : regulations for public premises) with no particular preference given, whatever the case study, either to natural or forced ventilation. ?3? ?4? ?5?

With reference to this background interest has been devoted to smoke production and spread in case of fire accomplishing a research intended to evaluate, by means of a simulation modeler, different conditions, if any of interest relating to safety, that develop in case studies considering, alternatively, natural vents or mechanical systems to exhaust smoke.

The research was conducted being aware of still actual necessity of validation, by means of real tests, for various formulated algorithms and procedures, but considering too as they constitute, at present, a real and most direct way for a better understanding of fire phenomena. And this especially with, at least, reference to the basic aspects of them. In fact, while the somewhat limited number of validation tests conducted has revealed scarce correspondence between predicted values and observed ones in complex cases (i.e.: examples involving numerous rooms and complex configurations), dependability of predicted results is quite general for basic examples involving only one room or no more than two or three rooms. ?6?

In these cases physics and related consolidated algorithms prevail with respect to other phenomena often modeled following results of limited observations.

The study was conducted adopting as tool the “consolidated fire modeler” developed at Building and Fire Research Laboratory of NIST (National Institute of Standards and Technology – Gaithersburg, Md, USA) named CFAST and belonging to the category of “zone modelers”. ?6? ?7??13?

THE ORIGINAL CASE STUDY

The interest for this kind of themes arose when involved in the fire protection design of an "historical theater" essentially wooden structured:

the "Teatro comunale PICCINNI " built in Bari (south of Italy) in the second half of 19th century.

Two different situations had to be examined:

- the Theater main hall (parterre + 4 rows of boxes and a gallery);
- the new space in the attic devoted, in the refurbishment design, as Theater's museum and conference hall.

For both it was explicitly asked, by the local Fire Brigade acting as control agency, to report on the efficiency, if any, and use of designed HVAC systems in case of fire.

For the new hall in the attic mandatory regulations obliged to adopt systems to exhaust smoke in case of fire.

THE THEATER'S MAIN HALL

While for the attic it was possible to realize either natural vents or use mechanical systems to exhaust smoke, for the Theater's main hall, being practically "englobed" within the remaining part of the building, there was no way to realize natural ventilation. (Fig. 1)

Consequently, having defined air conditioning characteristics compatible with the presence of fire, it was supposed to utilize someway this mechanical ventilation plant, eventually further improved, to realize better inner conditions in case of fire.

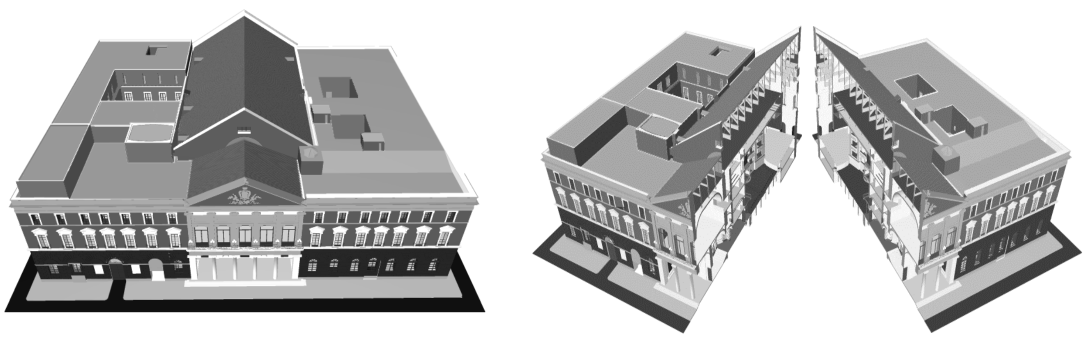


Fig 1 - The Theater as the central part of the town hall building

It were considered three different situations:

- absence of ventilation;
- only smoke exhaust;

- smoke exhaust +new air inlet (30 to 60 % of volume exhausted).

To define the Heat Release Rate it was considered the total amount of burning material (equivalent wood) present, a constrained type fire and an evolving curve that:

- reaches the maximum after 30';
- keeps the maximum value for further 60';
- goes then down to extinction during next 45';

for a total fire duration of 135 minutes.

These intervals definition derived too considering that structures collapse could occur only after 90' having been them fire verified for this amount of time.

In the very first phases simulations were limited to initial 34 minutes considering that:

- after the first 5-10 minutes people escape from the Theater;
- being the interested rooms endowed with self closing doors, fire rooms remain closed (unless cracks evaluated as an open percentage of present doors) during following minutes;
- after 20 minutes since fire start (presumably and as hypothesis) rescue teams open some doors to attack the fire.

The diagrams (Fig. 2) obtained using CFAST modeler showed that:

'no ventilation' determined:

- highest and dangerous vent fires (at doors opening after 20') and smoke opacity (TUHC);
- temperatures and fire values comparable with those in the 'ventilation' case;
- initial increase of pressure;
- lowest oxygen values;
- gases concentrations intermediate or comparable with those in the 'exhausting only' case;

'exhausting only' caused:

- highest temperatures, fires and gas concentrations;
- lowest vent fires and pressures;
- intermediate oxygen levels;
- smoke opacity (TUHC) comparable with that in the ‘ventilation’ case;

while ‘ventilation’ determined:

- lowest temperatures;
- lower vent fires (comparable to those in the ‘exhaust only’ case);
- almost stable room pressures;
- highest oxygen levels;
- lowest gases concentrations and smoke opacity (TUHC).

Extending simulations to the entire fire duration it were confirmed the same results.

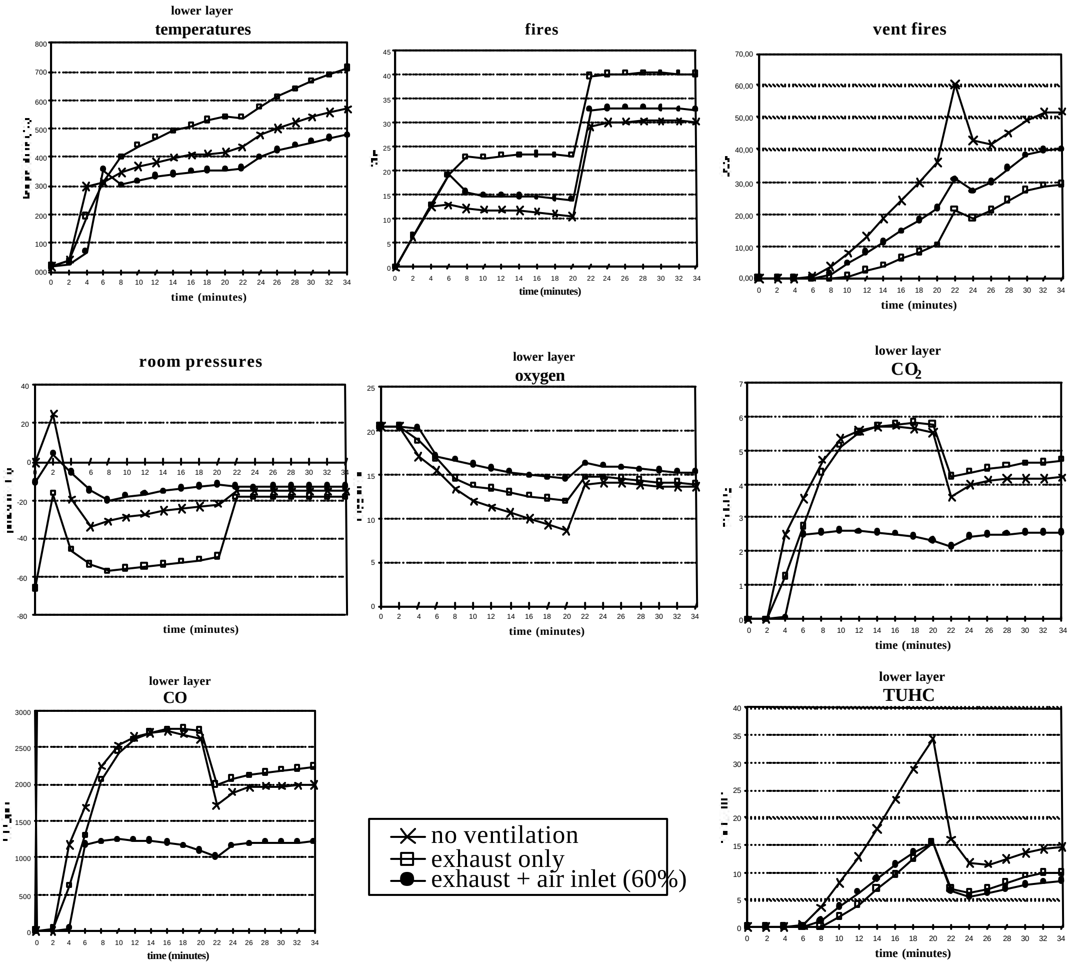


Fig. 2 - Theater main hall - CFAST diagrams (first 34 fire minutes)

THE NEW HALL IN THE ATTIC

Having obtained this kind of results for the Theater's main hall, the interest was devoted to the new hall in the attic.

Here too it had to be considered the presence of a quite relevant amount of wooden elements among which a significant role was played by the big and composite "palladiane" trusses and remaining roof elements (wooden slabs, secondary beams, etc.).

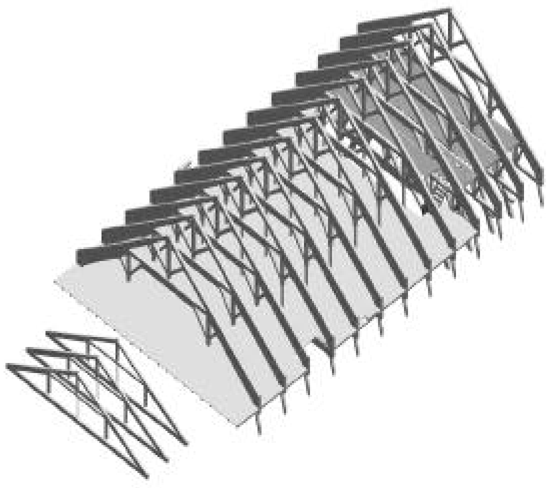


fig. 3 – Wooden structures of the attic

Fig. 4 – The attic as Theater’s museum and conference hall

It was decided, as for the Theater, to consider, to define the HRR curve, the total amount of burning materials present with a fire growth trend analogous to that previously described.

Adopting a "constrained" type of fire were so performed different fire simulations, using CFAST.

Substantially it was supposed to put all the burning materials in the center of the room, start the fire, verify which levels were determined according to oxygen percentages.

Even if here it was possible to realize, being at the top of the building, either a natural or forced ventilation solution, it had to be considered a mandatory prescription that obliged to adopt a mechanical system.
It was so modeled a system realizing a smoke exhaust of roughly 10 volumes per hour and a new air inlet varying between 30 to 60 % of exhausting volumes. Within the simulations it was included too a new aspect not present for the Theater: the existent windows with glass panes.
It was so considered that when the temperature inside reached roughly 100 °C these window panes were going to break so realizing a sudden opening of new vents.
Various simulations where performed and these permitted to evaluate, as more suitable for the study case, a value of 30% of new air inlet according to room pressures: an higher value, it was verified, would have increased smoke spread towards surrounding spaces.

Attention was so devoted to the following five different situations:

- no ventilation + window panes breakdown;
- no ventilation + fire resistant window panes;
- exhausting only (10 volumes/hour) + windows breakdown;
- exhausting only (10 volumes/hour) + fire resistant window panes;
- exhausting (10 volumes/hour) + 30% new air inlet + fire resistant window panes.
-

As obvious adopting fire resistant window panes there was not any more the occurrence of new vents opening.
As for the Theater the diagrams (fig. 5) showed that the best conditions were obtained adopting ventilation: smoke exhaust + new air inlet.

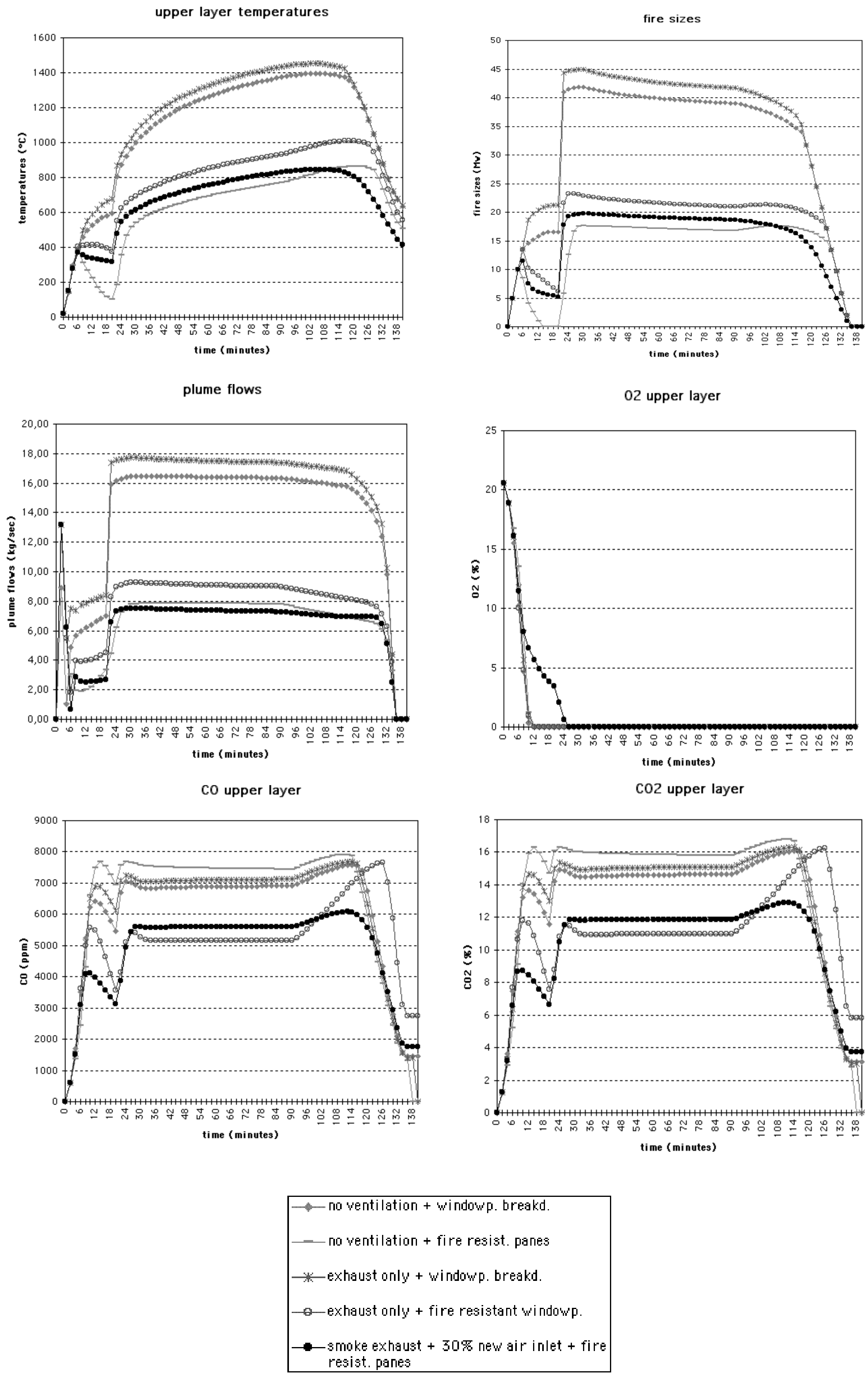


fig. 5 - The new hall in the attic - CFAST diagrams

In this latter case, in fact, we obtain:

- lower temperatures;
- lower fire levels;
- lower plume flows;
- lower gases levels (CO and CO_2);
- higher oxygen levels in the very first minutes.

Not realizing ventilation at all and/or exhausting only smokes revealed to cause, with the concurrent event of windowpanes breakdown (roughly after 5 minutes since the beginning of the fire and having reached 100°C), higher values for temperatures, fire sizes, plume flows and species concentrations (CO and CO_2).

Only considering fire resistant windowpanes the "no ventilation" solution shows temperatures, fire sizes and plume flows comparable with those obtained exhausting and introducing new air, but, nevertheless and as obvious, quite higher values of gases concentrations.

Here too it was hypothesized the rescue team arrival after about 20 minutes since the beginning of the fire. In all diagrams can be so easily recognized the sudden variation on curves caused by the doors openings. Same effect was noticed as deriving from the "new vents" determined by windowpanes breakdown.

A FEW CONSIDERATIONS

As a consequence of these simulation results for both the Theater and the new hall in the attic it was adopted, as the design solution, the one providing smoke exhaust and new air inlet. All fans were thought as endowed with "inverters" as means to control speeds and so air fluxes according to needs evaluated too by rescue teams.

For the Theater it where chosen apparatuses that could operate till the temperature of 800°C (water cooled); for the new hall in the attic, considering the effect of the water sprinkler system provided to lower

temperatures and wet wooden structures, fans tested to resist to a maximum of 400 °C.
In some way it was so adopted, as final solution, a cautious one that considers simulation results, but too the possibility to intervene to correct, according too to eventual successive new rules and/or recommendations, values of fluxes to exhaust and inlet.

As a matter of fact there are a few "common ideas" quite widely diffused among people involved in fire themes that is somewhat hard to modify. Usually, for instance, it is thought that the best thing to do, in case of fire, is to close everything avoiding, so, to feed oxygen to the fire. This often does not consider that, if the room interested by the fire has a relevant volume, the oxygen present within the room is, by itself, sufficient to develop a quite big fire and, moreover, that in this situation when a door is opened (i.e. by rescue team) a pernicious vent fire occurs together with a fast restarting of fire phenomena.
Another quite spread idea is that when is present a natural ventilation system it occurs a new air inlet through low vents while smoke goes outside through ceiling ones. Fire modelers algorithms, instead, consider a quite more complex behavior for vents where, according to different parameters varying during the fire, each vent can be characterized by both air inlet and smoke exhaust (or inner air exhaust). As a consequence, if this modeled behavior is correct, natural vents are more suitable to determine uncontrolled conditions within the room as more oxygen would determine bigger fires and so higher temperatures and pressures and so bigger fluxes through the vents and so bigger fires and so on.
A "controlled" ventilation, in the sense of predefined inlet and exhaust fluxes, seems, instead, to better control phenomena: pressures can be controlled, temperatures drop and so pyrolysis rate, smokes are exhausted determining only a predefined new air (and oxygen) inlet.
An other consideration seems to sustain effectiveness of mechanical ventilation: the so called Positive Pressure Ventilation (PPV) technique recently among those adopted by rescue teams to attach a fire.

By means of movable powered fans, and following a studied and specific procedure, big quantities of new air are inlet within the fire room having previously provided, on the opposite side of attach, a wall or ceiling opening to permit smoke to leave the room (or compartment) pushed out by the new air. The observed results do not include an increase of fire, but increasing in visibility (having eliminated smoke) and a decrease of temperatures: elements that permit to intervene more rapidly and in better safety conditions. ?8??9??10??11?

FURTHER SIMULATIONS TO ANALYZE PHENOMENA

All these considerations and the two case studies results determined an interest to develop more simulations to better analyze the subject and this with respect too to a point that does not seem not relevant: limit, if possible, damages caused by the fire.

This can be a quite important result for fires concerning historical buildings where is a priority objective to save people present but too, after that, to save the building and in all fire situations where has relevance destruction protection of stored burning materials (i.e. libraries, archives, museums and so on).

Different cases were so evaluated considering variations in :

- room typology;
- quantity of burning materials (i.e; HRR curve);
- dimensions, position and number of doors and windows.

For all cases have been compared the effects deriving from the activation of natural vents or, as alternative, the use of mechanical ventilation systems to exhaust smoke and inlet new air.

With reference to mechanical ventilation systems (HVAC), according to fire compartment characteristics, different values of exhaust volumes and new air inlet percentages have been evaluated to define optimal solutions that have showed to be quite strictly related to specific fire room characteristics.

Simulations showed that a value of ten times the fire room volume each hour had quite general significance for what concerned air and smoke to exhaust.

Percentages to inlet revealed to be related to the number of doors and/or windows present and their sealing characteristics in the sense that where more relevant was the number of openings and/or worse their airtight, better conditions were obtained adopting a lower value (roughly 30%) of new air inlet. This derived essentially considering room pressure as a significant safety factor since over pressures increase smoke spread towards surrounding rooms, while too low pressures can cause difficult doors (opening towards the exterior) operability and can increase air fluxes (feeding the fire) through existent "cracks".

More than a real conclusive statement this seemed, rather, to be something deriving from model limitations. As a matter of fact over pressures showed to be present in the early stages of the simulations: when the fire is growing and temperatures are arising. Later on the exhaust system makes up balancing plume flows. The modeler used does not permit to define start time for the air inlet plant and/or a variation, through time, of air fluxes values. Consequently every thing starts at the same moment (and for air fluxes with fixed values): fire, smoke exhaust and new air inlet. In the very first minutes, to stabilize pressures, it should be necessary to reduce (or post pone) the new air inlet avoiding, so, initial pressure picks. (fig. 6)

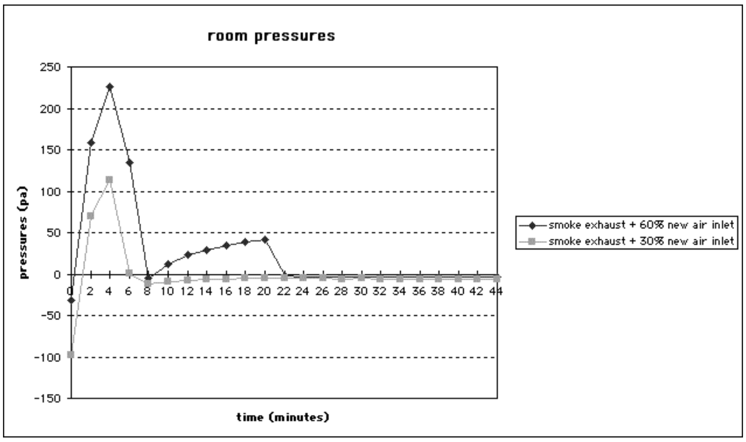


fig. 6 - Example of initial room pressure picks varying new air inlet percentages

Attention has been then devoted to remaining two variables:

- room typology;
- HRR curve maximum value.

For the first it where hypothesized and modeled three different room shapes:

- a cubic one;
- a somewhat flat one;
- a tower;

each endowed with only four doors (one each side).

Where so defined three case studies so configured:

Case 1 (fig.7)

Dimensions: 10 m x 10 m x 10 m (height)

n. 4 doors 1,50 m x 2,50 - two doors opened after 15 minutes since fire start (rescue team)

n.1 horizontal vent (ceiling): 1,00 m x 1,00 m (1 sq. meter total ceiling vent area)

n.2 vertical vents (low part of walls): 0,50 m x 2,00 m each (2 sq. meters total vertical vents area)

Total volume : 1000 cubic meters.

Case 2 (fig.8)

Dimensions: 8 m x 16 m x 8 m (height)

n. 4 doors 1,50 m x 2,50 - two doors opened after 15 minutes since fire start (rescue team).

n.2 horizontal vents (ceiling): 0,80 m x 0,80 m each (1,28 sq. meter total ceiling vent area)

n.4 vertical vents (low part of walls): 0,64 m x 1,00 m each (2,56 sq.meters total vertical vents area)

Total volume : 1024 cubic meters.

Case 3 (fig.9)

Dimensions: 8 m x 8 m x 16 m (height)

n. 4 doors 1,50 m x 2,50 - two doors opened after 15 minutes since fire start (rescue team).

n.1 horizontal vent (ceiling): 0,80 m x 0,80 m (0,64 sq. meter total ceiling vent area)

n.2 vertical vents (low part of walls): 0,64 m x 1,00 m each (1,28 sq.meters total vertical vents area)

Total volume : 1024 cubic meters.

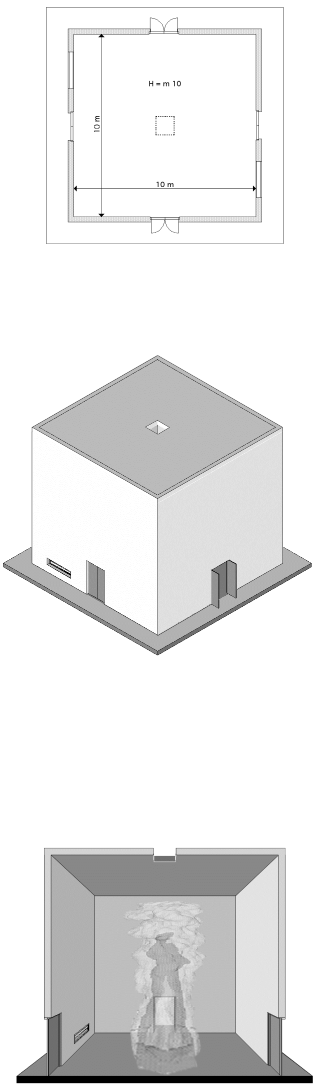


fig 7 - Case **1**

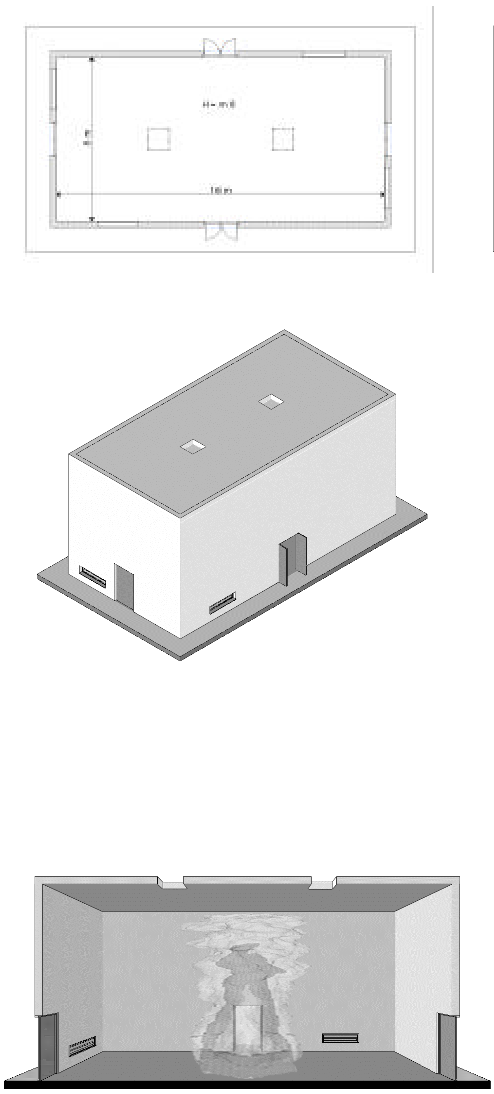


fig. 8 - Case **2**

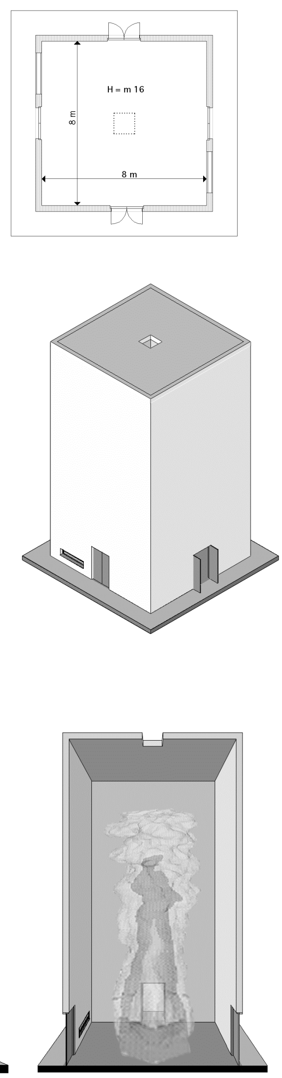


fig. 9 - Case **3**

As a first hypothesis it was supposed a maximum HRR value of 30 mW with a fire curve characterized by:

- an increasing initial period of 10 minutes;
- 20 minutes of a steady value of 30 mW;
- a final decreasing (to 0) period of 15 minutes;

for a total fire duration of 45 mi
nutes. (fig.10)

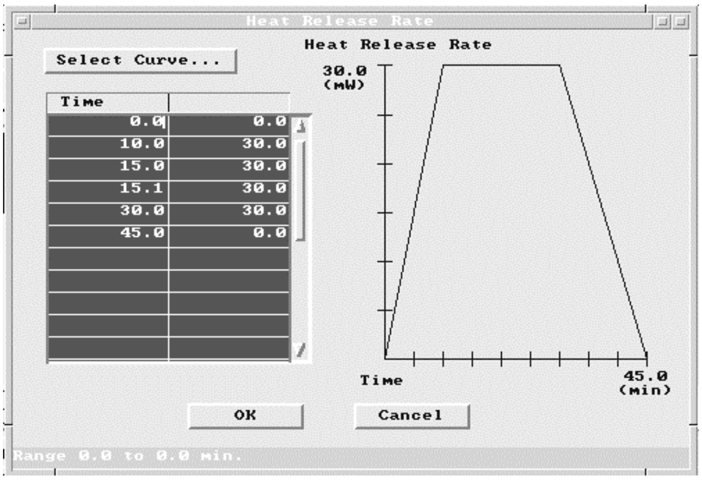


fig. 10 - The HRR curve

Dimensions of the natural vents were derived following the UNI 9494 norm specifically devoted to the subject. This norm establishes, among the other things, that for each ceiling vent has to be present a low opening having an area equivalent to two times that of the ceiling one. ?12?

Being characterized by essentially the same volume, for all three cases it was considered the same mechanical air ventilation system exhausting (from the top) 10 volumes (10.000 cubic meters) each hour and with a new air inlet (at the bottom) of 30%.

With this kind of set up it were performed first simulations. All cases showed to behave in almost the same way: the different typology did not seem to essentially modify phenomena. As can be noticed observing the diagrams (fig. 11) in all three cases natural ventilation causes:

- a somewhat continuous increase of temperatures with a pick after 15 minutes when the two doors are opened;

- a maximum value of HRR that practically reaches 30 mW: the maximum value.

In the first two cases flashover (600 °C) is reached after roughly 15 minutes. In the third 3-4 minutes before.

Utilizing the mechanical ventilation instead:

- temperature increases and then decreases in the first 15 minutes; it begins to increase again after doors opening;

- the maximum value reached of HRR is much lower: about 20 mW (10 mW less);

- flashover is reached roughly 10 minutes later (case 1: 29 minutes - case 2: 33 minutes)

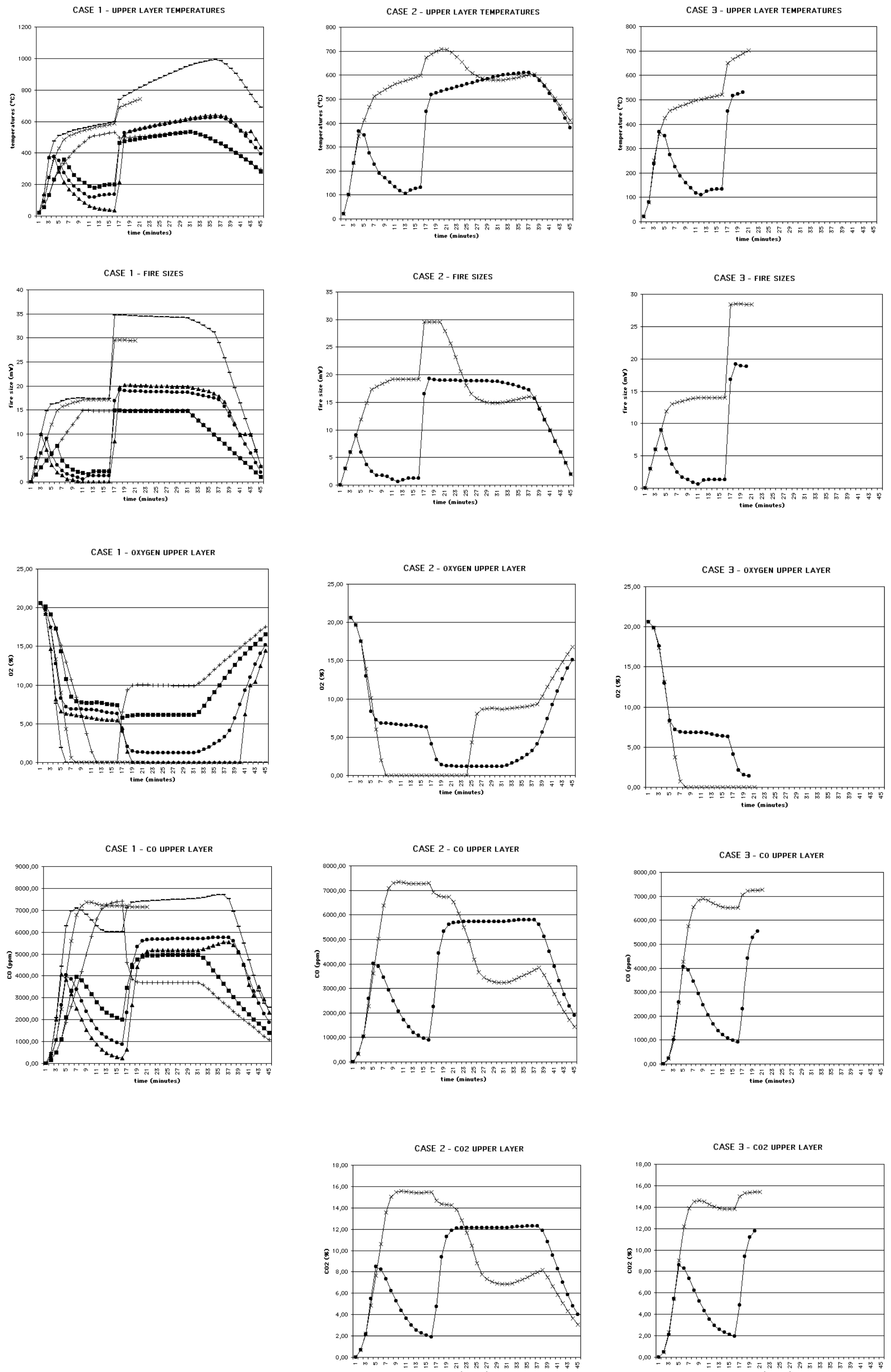
In all cases the mechanical ventilation shows to determine lower concentrations of gases (CO and CO_2) and higher oxygen percentages in the first 15 minutes.

Having obtained these results and having noticed that the room typology had scarce influence on main phenomena, more simulations were developed considering only the case 1.

It was so modified, maintaining the remaining characteristics, the maximum value of the HRR curve considering the amounts of 50 mW and a much lower one: 15 mW.

With 50 mW of HRR maximum the fire size reaches roughly 35 mW with the natural ventilation and less then 20 mW adopting forced ventilation.

Considering 15 mW this amount is reached by the fire either with the natural ventilation, either with the mechanical one, but with a delay, in the latter case, of 6-7 minutes; temperatures are consequently lower in the first 20 minutes.



Case 1 **Case 2** **Case 3**

fig. 11 - CFAST diagrams

CONCLUSIONS

It were performed, excluding various previews runs to analyze particular aspects (i.e. vents positions and/or dimensions) a total of 10 final different simulations. Three of them, as can be noticed from the diagrams, where stopped reached the first 25 minutes. After three days processing on a Pentium III - 800 MHz computer they were still running advancing by very small steps. This is a peculiarity of some of the algorithms used by CFAST that reduce time steps when operating on very small entities (in these cases, presumably, the oxygen percentages).
What obtained it is not supposed to be considered exhaustive, neither as a systematic study on the subject. The examples examined have, nevertheless, showed with evidence how better interior conditions realize when in presence of a mechanical ventilation system (assuring exhaust + new air inlet) properly designed and dimensioned and this with respect to all values relating to safety but, too, to building protection.

To summarize we can say that HVAC activation determines (according to model results):

- lower temperatures;
- lower fire sizes (due too to pyrolysis reduction consequent to temperature decrement);
- lower smoke opacity (TUHC) and toxic gases concentrations;
- lower pressure variations (pressures tend to stabilize);
- lower vents fires;
- higher oxygen percentages in the early stages;

while natural ventilation systems, even if determine a certain improvement of inner conditions (with respect to what happens without them), surely determines, if the fire is not differently fought, the complete combustion of all burning materials present.

While natural vents determine a general increasing of fire sizes (due to oxygen captured from outside through existent doors, windows and cracks or other vents) the use of a mechanical ventilation system seems to permit to regulate pressures and oxygen quantities and, consequently, determine a sort of "control on the fire".

Inferring intuitively, solicited by the graphs, the forced ventilation appears as an intermediate solution between the room sealed (unfeasible) and, at the opposite side, uncontrolled natural vents.

Obviously it has not to be disregarded that, differently from natural vents whose operation can be much less critical, a great concern has to be devoted, if deciding to adopt HVAC systems, to reliability of mechanical apparatuses whose efficiency has to be assured in the conditions that are going to develop during a fire. It should be, moreover, cautiously evaluated, time to time, if it is worthwhile, in terms of effective benefits, to pass from systems whose working is quite simple and essentially sure to more complex and needing more maintenance ones.

At the very end it seems that, more than implementing extensive further computer simulations, it should be more appropriate to perform real tests in order to validate the showed simulation results. Understood the phenomena, each case would be adequately studied and dimensioned according to its specific variables.

If validated, the results showed could play a significant role defining adequate solutions to fire protect buildings.

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FIRE SAFETY UPGRADES FOR HISTORICALLY SIGNIFICANT BUILDINGS: THE PROCESS AND THE PROMISE

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Keywords: Fire-Life Safety; Preservation; Protection

Over the years, many of our historic treasures have been severely damaged or lost to the ravages of fire. In November of 1992, Windsor Castle, built in 1066 by William the Conqueror, had a fire break out in the northeast portion of the building. The fire quickly spread to eventually damage over 100 rooms destroying irreplaceable treasures. It took over 15 hours for 250 firefighters to control the blaze. On December 7, 2002, a fire in the Cowgate area of Old Town in Edinburgh, Scotland ravaged the area, destroying numerous buildings in that historic district. Ironically, the building where the fire began was reported to have been provided with fire sprinklers. Unfortunately, the sprinkler systems were not functional at the time of the blaze. In New Bedford, Massachusetts, a recent fire nearly destroyed the 122-year old downtown building housing the Moby Dick Marine Specialties store.

From castles to down town districts to individual buildings, we continue to lose many historic buildings in the world every year to the ravages of fire. Faced with such irreplaceable loses, what can be done to protect our cultural heritage properties while maintaining the features that define them as historic buildings?

This presentation suggests an approach to provide needed fire and life safety for historic facilities while maintaining sensitivity to their significant architectural features. It covers fire safety for the preservation process, the specific elements of the approach, and how to deliver the promise of fire safety with sensitivity to the building's design. Following the presentation of the process, approach, and promise, we'll review some case studies to see how the approach works.

Fire safety improvement for historic facilities is a four-step process. First, we must establish project goals. Next, we need to evaluate existing building conditions related to fire and life safety issues. Once we have the goals and existing conditions established, we need to determine the implications of local building and fire codes for the project. Finally, we need to blend these considerations together into the development of our fire safety plan.

For historically significant buildings, there are five primary goals that need to be established when pursuing a fire safety upgrade program. First is the safety to life goal. In broad terms, this goal may be stated as reducing the probability of injury or death from fire for building occupants and those near the building. This objective also must consider the building's design with regard to providing a reasonable level of safety for the fire fighters and emergency responders during search and rescue operations.

The second goal is to address the safety from the effects of the fire. This goal must consider the ability of the building's structure to maintain its integrity and that of the egress paths to allow occupants a safe path during the time needed to egress from the building. A second consideration of this goal is to limit the exposure the building presents to surrounding buildings. Finally, this goal must also consider the provision of reasonable access to the building by emergency equipment and access into the building by the emergency responders.

The third goal is for continuity of operation of the facility. This goal must address the limitation of fire and smoke spread issues with specific regard to the damageability of structural elements as well as the building's contents. In this area, one must consider the need for protection of structural systems, the damageability of surfaces, and irreplaceable contents in the facility.

The fourth goal is access to the facility for the disabled. This goal must address how the development of a fire safety egress plan can remove barriers that will improve egress as well as provide improved access.

The final goal is that of retaining the building's historic significance. This goal must address how the fire safety solutions will ensure reasonable care in design of fire safety upgrades to preserve the original quality or character of the building's interior and exterior. These issues can include being sensitive to exterior facades, retaining features of the architectural design such as exposed structural elements, and retaining historic interior finishes.

With these goals in mind, the next step is to evaluate existing conditions as they relate to basic fire safety needs as well as to specific requirements of local codes and standards. The first area of consideration is that of the structural systems for the building. This will include not only a general evaluation of the type of structure (combustible, noncombustible, and fire resistive rating), it will also need to consider issues of unprotected vertical and horizontal openings. In addition, one must consider the historical significance of the various structural items that may be in conflict with current code requirements or fire safety needs. This could include considerations of grand open spaces connecting numerous floors (as a rotunda in a capitol building or upper level viewing galleries in a reception hall of a castle) or items such as unprotected structural beams and columns.

Next comes the consideration of interior partitions and finishes. Do partitions provide fire resistive separations between occupancy use areas? Are egress corridors separated from occupied spaces? Do doors to egress corridors have operable transoms? Are wall and floor penetrations properly protected to prevent smoke movement? What materials are used for wall coverings? Do wall coverings, tapestries, and draperies have historic significance?

The next area of consideration is the building systems including mechanical, electrical, and plumbing. Mechanical systems need to be evaluated considering how air is distributed in the building. Many historic buildings were built prior to the advent of modern air conditioning systems and were dependent on natural flow of air through the building. In such cases, were these natural ventilation passages reused or were they abandoned? In either case, what impact will these air ways have on potential smoke movement in the building?

Similar to the issue of air handling systems, many historic buildings were built before the common use of electricity. The electrical system needs to be reviewed with respect to how it was installed, how is the wiring protected, and what load capacity does the system have relative to the building's basic needs and that of any necessary fire alarm and communications systems?

Plumbing systems need to be examined to assure no unprotected vertical or horizontal openings have been created from these systems. The main water service connection needs to be evaluated for the ability to use it as the supply for sprinkler or standpipe systems.

Fire detection, alarm and suppression systems need to be evaluated for their application to areas protected, extent of coverage, age and condition, and ability to extend to additional areas as needed.

Next, egress needs to be evaluated for its appropriateness to the current use of the building. An egress system that was acceptable for an office use occupancy will generally be deficient in both capacity and locations when the building has been turned into a museum. The number of exits, their width, and location must be determined. Travel distances must be calculated and dead end exit paths must be identified.

Any hazardous use areas in the building must be identified. These can range from storage closets for volatile or combustible liquids used in maintenance activities to woodworking or printing shops. Such areas need to be evaluated for the type of fire rated separation provided and extent of automatic fire protection systems installed.

Once we have completed our inventory of the facility, it is time to evaluate local codes and standards to understand statutory requirements for the facility. Keep in mind that the typical fire code is a maintenance and use document, meaning the fire code addresses how you can operate in a building, how you deal with fire hazards of occupancy and how systems must be maintained. The building code, however, deals with the requirements involved with building design features based on the extent of changes being made to the building.

For instance, most building codes do not have retroactive requirements for existing buildings unless the structure is relocated or is deemed an unsafe building or a fire hazard. Building codes will typically require any remodeling to an existing building to comply with the provisions of the current code. The extent of work being performed will generally define what aspects of the code become retroactive requirements. With additions to a building, the building code will typically permit the existing facility to remain unchanged provided the new addition is separated and fully complies with the code. The challenge comes when one is doing a renovation/restoration project. In these cases, it is imperative to meet early on with local officials to establish what can remain unchanged, what may need modification, and what will be mandated to change. Fortunately, most building codes now have sections that deal with historic structures and a means of developing equivalence to the basic code requirements.

From the existing conditions results and the review of code requirements, we can identify features of the building that will need to be changed to meet our goals. For instance, can an open stair continue to be used or do we need to develop a way to enclose it? Can we develop equivalent performance to what the code requires for fire resistance rating by developing more reliable fire detection and suppression? Germane to these considerations will be the items the project's preservationist identifies as the historic features of the building that must be preserved. With a little prodding, one can usually find ways to retain the features of historic significance while improving the fire safety that is provided.

Where equivalencies to the code requirements are necessary to maintain historic elements, it will be necessary to establish the code intent of the specific requirement, then develop alternative solutions that can be demonstrated to meet the intent. Demonstration of how the solution meets the intent can often be demonstrated through fire modeling techniques or other technical justification. When confronted with such equivalencies it is important to maintain a regular dialog with the local code officials to be sure all parties agree to the approach and will be comfortable that the solution can be built properly and adequately maintained. In many preservation projects, the local officials become a key part of the project team, helping to jointly develop solutions that all stakeholders can agree upon.

Once the aspects of the fire safety plan have been agreed upon and equivalent solutions have been established, the final part is the documentation of the plan. The documentation usually will include a description of the process followed, a presentation of the fire and life safety goals, a complete listing of existing conditions (related to fire and life safety aspects), listing of applicable code requirements (giving specific requirements and code references), and an identification of which code items will be met through equivalent means. For items being addressed by equivalent means, a section in the report will be necessary that identifies the code section, explains that section's intent, describes what alternative solution is to be followed, and explains how the alternative meets the code intent. Typically, the equivalencies will need supporting documentation in an appendix (such as egress calculations and fire models).

The specifics of the plan follow next. This includes what changes are to be conducted to meet the fire and life safety goals. These specifics will cover structural changes, egress, fire detection, alarm, and suppression systems, and building access. All of the items covered in the report will of course be supplemented by drawings and specifications documenting how the changes are to be implemented.

The key to a successful preservation project is in the basic elements of the approach. What aspects of the building are critical to its historical significance and therefore cannot be changed? What aspects present such grave fire and life safety hazards that they must be changed? And, what do you do to resolve conflicts when the items to be changed are of historic significance?

Things that cannot be changed typically are historically significant features, irreplaceable finishes, and exterior appearance. Things that must change are those that pose an unacceptable level of risk to occupants or the integrity of the building where there are no practical alternatives available to resolve these challenges. The best way to resolve conflicts between fire and life safety goals, code requirements, and preservation issues comes from open communication and teamwork between the designers, the code officials, the owners, and the preservationists. This team must work together to develop consensus solutions supported by technical justification.

How do we deliver the promise of maintaining sensitivity to historic features? Through a team approach that develops well documented facility design solutions, well defined and documented fire safety systems design, and technical support to the construction team throughout the construction process.

Now, let’s look at three case studies where this approach has been used on different levels of complexity. The first will be a project where the primary focus was on the installation of new fire safety systems while being sensitive to existing finishes. The second will demonstrate how fire modeling approaches can be used to justify equivalencies used in fire safety improvements programs. The third will be an application of the process on an extensive preservation project.

The Palace Hotel opened in 1912 as a luxury hotel in the heart of the cultural center of Madrid. The Palace Hotel is a landmark in Madrid located just minutes from the Prado and Thyssen museums. It houses over 400 guest rooms, a retail center, several restaurants, and a central lobby whose rotunda has been the center of Madrid’s social life. When Starwood purchased the CIGA hotel chain, the Palace Hotel was one of the jewels included.

To assure that the newly renamed Westin Palace Hotel met not only the standards of luxury, but also Starwood’s fire safety standards, a fire safety evaluation of the property was conducted. The study identified areas where the Palace needed improvements in fire and life safety to meet Starwood’s requirements. These improvement needs were documented in a fire safety plan to be implemented concurrent with a general face-lift of the property. A key to the program was to be sure that the fire safety improvements would be sensitive to the historic significance of the building.

The primary fire safety improvements included standpipe system upgrades, the provision of complete automatic sprinkler protection, a new water supply connection and fire pump, and a new fire detection and alarm system throughout the facility. In addition to the typical detailed instructions in the drawings and specifications to the contractor regarding the fire safety upgrades, additional direction regarding sprinkler finishes and location was given to assure that they would blend into the existing ceilings. Standpipe and sprinkler piping and wiring for the fire alarm systems were all concealed. Smoke detector and sprinkler locations were coordinated with existing ceilings and light fixture locations.

Regular inspections were made during construction to review the progress and answer the contractors' questions regarding field conditions. The extra care taken during the process assured the result would maintain the hotel's lavish décor while meeting the owner's desired level of fire and life safety. Next, let's look at how fire modeling may be used to analyze options for improving egress in historic facilities.

The U.S. Capitol is one of the most recognized government facilities in the world. The construction of the U.S. Capitol began in 1793. By 1800 the building consisted only of what is now referred to as the north wing. By 1846 the south wing had been completed, while the construction of the Capitol dome was still in progress.

An aerial view of the Capitol Complex in 1923 shows the building as it essentially appears today. The Thomas Jefferson Building, which is home to the Library of Congress, can be seen in the Background and the House Office

Building (Cannon) and Senate Office Building (Russell) can be seen on the right and the left of the Capitol respectively.

The footprint of the Capitol is 175,170 square feet and consists of a total square footage of 16 ½ acres. The Capitol has 540 rooms and receives from three to five million visitors each year.

The Capitol's most prominent architectural feature is the dome. The Rotunda is 96 feet in diameter and 180 feet 3 inches from the floor to the canopy. The Capitol has five levels with a total height from grade to the top of the Statue of Freedom of 288 feet.

Committee rooms and offices occupy the first level of the Capitol. Public accessible areas on this level include the Hall of Columns, Brumidi Corridors, the Old Supreme Court Chamber, and the Crypt.

The Chambers of the House (South Wing) and Senate (North Wing) as well as offices of the congressional leadership are located on the second level. The major public areas on this level include the Rotunda, National Statuary Hall, and the Old Senate Chamber.

The third level accommodates offices, committee rooms, galleries and press area.
The forth level provides some additional office space and support areas.

The fire and life safety program for the Capitol has been developed as a balanced fire safety approach including automatic sprinkler protection, smoke detection, compartmentation with horizontal egress, and smoke removal capability. Equivalencies have been developed to address the numerous open stairs, and the overall building egress arrangement. In addition to the egress system, equivalencies have been developed to address the rotunda's height, occupant load, and interconnection of levels.

In the development of the egress equivalencies, criteria were established regarding the definition of safe egress in terms of visibility, level of carbon monoxide, and maximum temperature within egress corridors. Fire modeling was used to evaluate how the fire safety systems would deal with various fire scenarios relative to the fire safety goals.
The resulting design was shown to meet or exceed the goals under each credible fire scenario.

This FDS rendering shows a slice file representing visibility at approximately 1.83 meters (6-feet) above the third floor level. The rendering indicates the exhaust effect at maintaining tenable visibility conditions within the 3rd Floor corridor at 507 seconds into the simulation.

The Texas Capitol construction started in 1882 and was completed in 1888. As shown in the architect's original plans, the building layout provided grand open spaces with corridor widths in excess of 20 feet. Individual offices were spacious with a natural ventilation system that brought cool fresh air from the basement through the entire building in the summer and warm air from the numerous fireplaces in the winter.

Over the years, the growth of the state warranted the increase in the number of senators and representatives. As the number of elected officials grew, the offices began to become subdivided so that all could have their office in the Capitol building. With the growth of the population of elected officials came the growth of their support staffs requiring yet additional space.

By 1989, the building was housing more than twice the number of occupants it was originally designed to hold. Corridors were narrow and offices were cramped. In addition, the natural venting systems had long since been replaced with central air handling systems supplemented by window air conditioners and portable heaters.

Although smaller fires had occurred over the years, a fire in the Lieutenant Governor's quarters in 1983 came dangerously close to destroying the entire building. The fire brought the need for review of the building's fire and life safety clearly into focus. In 1989, the Texas Governor appointed a State Preservation Board to "preserve, maintain, and restore" the Capitol and other buildings on the Capitol grounds. The board decided that the only way to properly restore the building to its original grace and grandeur would be to limit the number of offices to those originally provided. This forced the need to build additional office space in a separate building. The legislature felt their offices must all be connected to the Capitol. The only way to accomplish this without disturbing the historical significance of the Capitol building site views and grounds would be to have the new facility built underground.

Major fire safety issues identified in a survey of the Capitol were related to structural fire safety, egress, and limited fire safety systems. As typical of building's of its vintage, the Capitol's structure consisted of wrought iron beams, a wood roof deck, and no fire protection of the structural support of the dome. Alterations over the years had installed combustible interior partitions throughout, suspended ceilings below previous ceilings that were not removed, and created unprotected openings and non-fire stopped combustible interstitial spaces.

Egress issues included open stairs, exit stairs that discharged into the building, insufficient exit capacity, excessive travel distances, dead end corridors, emergency windows used as primary means of egress, and egress doors swinging against the direction of exit travel.

Automatic sprinkler protection only covered limited areas. Similarly, standpipes were limited in coverage and water supply. Fire detection and alarm devices covered limited areas, and many of the alarm zones were either in trouble or were not functional.

Adding to the list of problems with existing fire safety provisions were three driving issues of the project planning:

?? How could we interface the new extension with the existing building?

?? How do we provide the fire safety upgrades without compromising preservation issues?

?? How can we deliver the project within the budget established by legislature?

After two years of building assessment, design alternatives analysis, development of code equivalencies, and regular meetings with the Preservation Board, the final fire and life safety plan was approved. The plan established protection schemes and equivalencies to allow the structural frame, floor construction, and roof construction to remain unchanged. These equivalencies were supported by the installation of complete automatic sprinkler protection, increased number of fire department use standpipes, and new fire pumps (with emergency power).

Addressable smoke detection devices were provided throughout the public areas, at each level around the rotunda, in all elevator lobbies, and in HVAC equipment. Audible and visual fire alarms were provided throughout. These alarms were supplemented by one-way voice alarms and two-way fire department communications.

All vertical fire penetrations were fire-stopped. Transoms over corridor doors were sealed and provided with a sprinkler located on each side of the glass.

The building was zoned into three zones per floor to allow quicker identification of a fire incident and staged egress. The new addition was completely separated by two hour fire resistive construction.

In addition to the sealing of transoms on upper floors, the basement level was provide with new one hour rated corridors. To meet the egress needs for the population load in the library, a new fire stair was installed. Chambers that were previously open to the exit corridors were separated by glass partitions with widow sprinkler protection on each side of the glass. The open egress stairs at the ends of the wings were provided with similar glass enclosures to retain the historic significance of maintaining a visual connection from the corridors to the Capitol grounds.

In addition to the fire safety features, new mechanical, electrical, and plumbing systems were provided throughout. A new emergency power generator was provided. The rotunda's marble railing had a new brass handrail added. And handicapped access was provide to all areas of the building.

Construction on the project was begun on the extension in 1990 and the restoration project started in 1991. The project was completed in 1995.

The three case studies demonstrate how fire and life safety upgrades can be successfully conducted while remaining sensitive to historic design features. We need to continue to preserve our buildings, yet we need to ensure that we provide an equal focus on fire and life safety aspects so that future generations will be able enjoy these historic treasures.