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Passive Fire Protection in Building Construction

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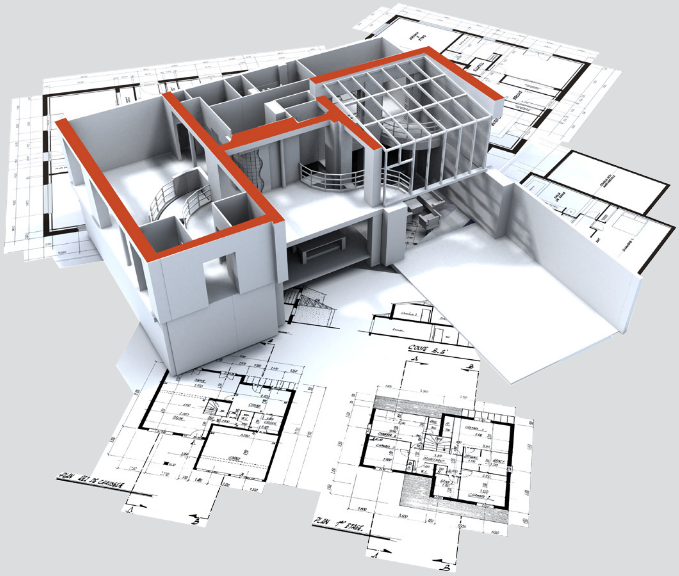
1. Introduction

1.1 Fire prevention

- Fire prevention is a crucial consideration for those who are responsible for the design, specification, and construction of new and refurbished buildings. It also plays a significant consideration in the ongoing maintenance of occupied premises. As causes of fire are often unpredictable, design measures are taken to influence the formation and spread of fire, smoke and toxic gasses.

- Fire safety in buildings covers the safety of occupants, fire fighters, building and contents together with the buildings in the vicinity. It is necessary to reduce to within acceptable limits the potential threats to occupants during the course of evacuation. It is also necessary to reduce the fire damage to the building and its contents; therefore it is essential to contain the fire as much as possible within the vicinity of its origin.



Effective firefighting in a building is often achieved through a combination of Active and Passive systems, and they should be designed and used in conjunction with each other to create a balanced approach to fire protection

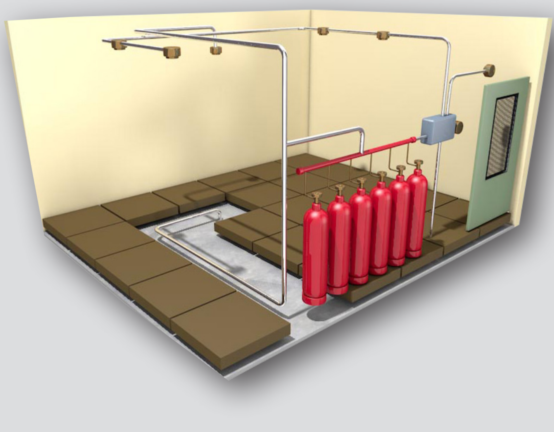
1.2 Active systems

- Active systems are designed to react on the outbreak of a fire, heat or smoke. These systems are primarily in the form of detection and suppression.

- Detection systems such as smoke or heat are designed to activate relevant systems as well as alerting occupants in the building, starting the evacuation process.

- Suppression systems are designed to prevent the growth of the fire by means of sprinkler systems, halogen installations, fire extinguishers or other proactive mechanical systems.

Both systems usually depend on a reliable power source and must be regularly inspected and maintained to remain effective during the life cycle of the building.

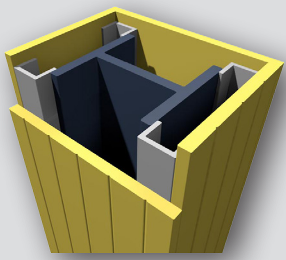


1.3 Passive systems

Passive fire prevention is an integral component which is designed to be built into the fabric of the structure, and require no additional energy or human intervention to act.

Passive protection includes elements of the building construction such as structural protection, compartmentation and can also support smoke management systems by providing fire resistance to smoke extract ducts.

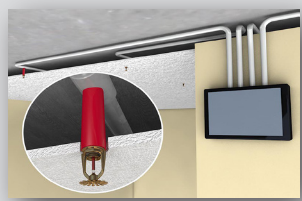
1.4 Structural fire protection



Fire resistance of structural elements would ensure that they are structurally stable when exposed to fire and therefore occupants and fire brigades are not exposed to the risk of a collapse of the structure.

Many building material suffer from loss of strength when exposed to high temperatures and the behavior of such materials differ greatly.

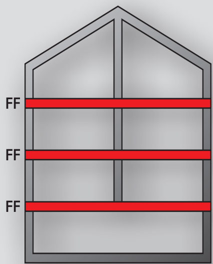
1.5 Smoke management system

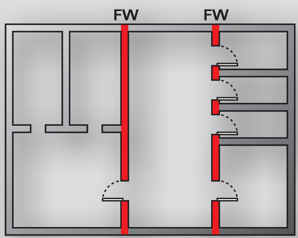


Smoke behaves very differently depending on building design, but the primary objective is to reduce the hazard due to smoke by controlling its movement, and by reducing its concentration to increase visibility.

1.6 Compartmentation

- There is one globally applied principle for fire safety which forms the basis for controlling the spread of fire, smoke & toxic gasses. It is compartmentation, also known as fire cells/compartments.
- Fire cells/compartments are generally included in the building design to limit the spread of fire, smoke & toxic gasses by containing the fire in a certain vicinity of the building, for a set period of time, thus providing protected escape routes, extending the evacuation & response times, and minimising building damage.
- This is achieved by dividing or sub-dividing the building into a series of zones separated with fire rated elements such as walls and floors.





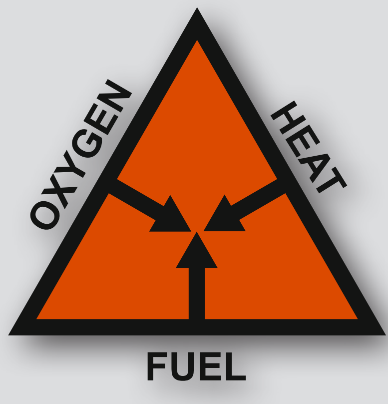
The fire resistance of an element is determined by its ability to resist fire by maintaining its stability (load capacity), integrity and insulation which is normally expressed in hours of resistance. The three requirements can be defined as:

- Stability (load bearing capacity) – is the ability of the element to maintain the load without collapse.
- Integrity – is the ability of the element to resist the development of cracks or voids allowing the passage of flames, smoke or toxic gasses to pass.
- Insulation – is the ability of the element to prevent heat transfer from one element face to another.

2. Basic knowledge

2.1 The fire triangle

- Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, emitting heat, light, flame and the emission of sound.There are three elements, heat, fuel and oxygen which form a fire triangle and each element needs to be present to sustain the oxidation process. Therefore the principle to extinguish or control a fire would be to remove one of these elements.



According to the National Fire Protection Association (NFPA) a fire can be classified by the type of fuel they burn:

- **Class A**
  Combustible solid material such as wood, paper, fabric, plastic
- **Class B**
  Combustible liquids and gasses such as oil, gasoline, paint, methane, hydrogen, acetylene
- **Class C**
  Energized electrical fires such as wiring, circuit breakers or fuse boxes
- **Class D**
  Combustible metals such as magnesium, sodium, potassium, titanium, zirconium

2.2 Extinguishing

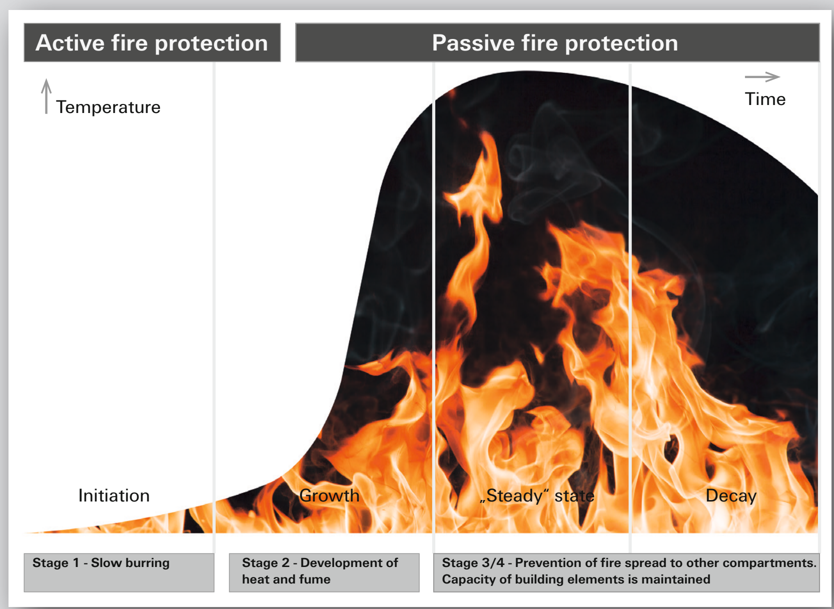
- For each class of fire there are various options for suppression, these are designed to suit the characteristic of each class of material, whether that be to remove the oxygen flow, cool the heat being generated or remove the fuel state, which will extinguish the fire.

However, caution must be taken to use the correct extinguishing method for each class of fire or it could have an adverse effect.

2.3 Fire growth

Fire generally starts small and increases with time and undergoes a number of phases from the ignition to decay by extinguishing or suppression. There are four stages in total:

- Stage 1 – Growth, also known as ignition, involves bringing together a heat source and a suitable fuel in a way that a continuing combustion results.
- Stage 2 – Development, a plume of smoke begins to develop, the temperature of fire gasses increases and begins to move away from centerline of plume.
  - Flashover – Temperature rapidly increases, additional fuel packages become available, fuel packages release combustible gasses, flashover occurs when compartment temperature reaches +500 °C.
- Stage 3 – Steady or can be known as stable. Overall compartment temperature layer at ceiling increases.
- Stage 4 – Decay or can be known as cooling, Heat release declines as fuel is consumed, volume of fire diminishes, temperature of compartment declines, fuel is reduced to mass of glowing members.



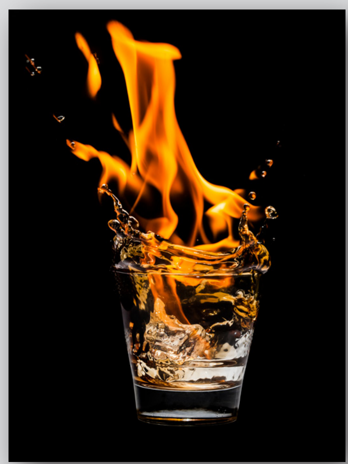
The illustration shows the four stages and where active and passive fire protection measures will act.

2.4 Spread

Fire could spread from one compartment to another with the loss of integrity of the fire resisting element such as an open door, or unsealed openings for services such as pipes, cables, ventilation or unsealed openings around such services. It could also be possible for a fire to spread through external flames projecting via the façade to the upper floors or adjacent building in the vicinity.

Additionally, when looking at fire protection we need to consider heat transfer or insulation value that would be required in order to maintain the seal or element as designed.

2.5 Reaction & resistance to fire



The reaction of a material in a fire is often confused with the resistance of an element in a fire:

- Reaction to fire relates to the combustibility and ignitability of a material i.e. its contribution to fire development and spread, rather than its ability to resist the passage of fire.
- Resistance to fire determines the likely behavior of an element of construction when subjected to a fully developed fire.

2.6 Areas of application

Fire cells/compartments are generally included in the building design as a requirement of the buildings functional or intended use. Over the life cycle of the building these cells/compartments may change, in size shape or requirement. However, the four application areas which should always be considered and could hinder the compartmentation principle are:

- **Construction joints**
  - A construction joint or movement joint is an assembly designed to safely absorb the heat-induced expansion and contraction of construction materials; it also absorbs vibration and allows movement due to ground settlement, thermal expansion or earthquakes.
- **Cavity barriers**
  - Cavity barriers are usually considered between two 'skins' separated by a hollow space (cavity). The skins can be either masonry brick / concrete block or drywall systems. They have been design to divide the area into separate spaces.
- **Service penetrations**
  - A service penetration is an opening designed and created to accommodate the passage of a mechanical, electrical service or structural element.
- **Membrane barriers**
  - Membrane barrier is an opening made through one side of the cavity wall, floor, ceiling of an assembly allowing exposure to the cavity.

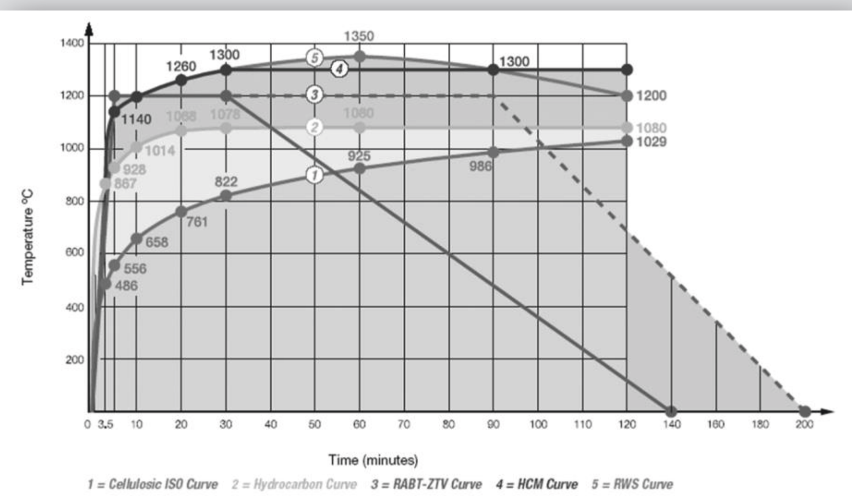
3. How firestop products work

Firestop products are designed to work in different ways to withstand the thermal and mechanical pressures applied during a fire, whilst maintaining its functionality as a firestop.

- Intumescent insulating (Char Forming) - is a substance that swells as a result of heat or flame exposure, it increases in volume and decreases in density. Upon exposure to heat the material produces a light charring (Carbon) to its outer surface to form an insulating layer. The charred surface is a poor conductor of heat and protects the covered surface.
- Fire Resistant – is a non-burning material which does not decompose and remains integral throughout the fire.
- Intumescent with pressure (Graphite) – a more substantial charring is generated in conjunction with a quantifiable expansion pressure. The material can be used around nonmetallic service penetrations. The expansion closes the void that would have developed once the service penetration had melted and burned away.
- Endothermic – is a chemical reaction which absorbs energy (heat) and releases water vapor to cool the surface.

4. Fire testing, assessment and certification

In many buildings there is a requirement for products and materials to resist the passage of fire and its byproducts. These products and materials help to control the growth and spread of the fire. As explained above, the location and period of fire resistance required for construction products is determined by the relevant legislation, codes of practice or the accepting authority.



Therefore a number of test standards are used to show the performance of a product or assembly under a generalised fire situation. In a generalised fire test, the specimen is exposed to a controlled internationally-accepted standard time/temperature and pressure regime which is intended to represent a post flashover condition. Flashover is the point at which all objects in the fire test have ignited. In an actual (real) fire, the time period to flashover can vary depending on aspects such as the nature of the fire load, compartment size and shape and the available ventilation. The performance of the test specimen is monitored on the base criteria as described in the relevant standard.

- The Test Report: Once a product has been tested, a report will be issued that will contain all details of the tested specimen, together with information on the size / configuration of the sample. The test report itself is a purely factual document, stating times to failure of the specimen and other relevant information such as observations taken at time of test, graphs showing furnace and specimen temperatures and distortions.

- The Classification Report: A classification report can be written in accordance with BS EN 13501-2 after an EN test or series of tests which may include other tests such as ambient or low temperature smoke leakage tests. The classification report and a field of direct applications will give the scope of use of the product.

- Assessment Report: Can be produced to bring all items of test data into a single document, the Assessment Report will clearly define the full scope of the product.

5. Standards

A series of fire standards have been developed and produced for use in different countries over the years, for example: - UK use the BS476 series (British Standard Institute), while Germany use the DIN 4102 series (Deutsches Institut fur Normung), and the Americans follow the ASTM series (American Society of Testing Materials) however with the advent of a harmonised European system EN fire classification is now being used in preparation for CE Marking of the product.

5.1 European & CE marking

In the case of fire stopping materials, the product standard has been produced by EOTA (European Organisation for Technical Approvals) under direction for the European Commission, and is known as European Technical Approval Guideline, ETAG 026, to which there are three parts.

At the European level, new harmonised fire classification systems have been introduced, including BS EN 13501-1 and BS EN 13501-2 for reaction to fire and for resistance to fire respectively. The fire classification system calls up specific harmonised EN fire tests for stated applications. These fire tests are BS EN 1366-3 for penetration seals, and BS EN 1366-4 for linear fire stopping systems.

It is important to consider that whilst the above test methods and classification deal with the resistance to fire requirements, generally this is not enough for CE marking.

The CPR (Construction Products Regulation) lays out six essential requirements (ER's) that may need to be satisfied before a product can be placed into the European market. ETAG 026 will allow a Notified Body to produce an ETA (European Technical Approval). This approval will consider which Essential Requirements need to be fulfilled. This may include taking account of other test information such as performance under internal and external exposure conditions, cold state, load bearing capacity, impact resistance, durability, moisture resistance, etc.

5.2 ASTM & UL Listing

The American Society for Testing and Materials, also known as ASTM International, is a standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems and services.

The "E" series relates to the topic of fire protection, ASTM E814 for service penetrations and ASTM E1966 relates to fire resistance joints. The ASTM standards are the basis for such organisations such as UL (Underwriters Laboratory) who have adapted the test standard and added additional aspects to create their own series.

Underwriters Laboratory is the most common and comprehensive independent testing laboratory established to investigate materials, devices, products, constructions, methods and systems with respect to hazards affecting life safety. With a similar purpose to the CE Mark, the UL Mark is a sign of recognition to consumers that the product meets safety requirements, from the series of testing a field of applications is produced in the form of a listed system - similar to the EN Assessment/Classification Report.

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