TALAT
Training in Aluminium Application Technologies

TALAT Lectures 2501

Fire Protection and Regulation

16 pages, 6 Figures

Basic Level

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Objectives:

- to understand the characteristics of fire, the conditions for its occurrence and development
- to introduce definition and terms of fire resistance and protection

Prerequisites:

General engineering or physics background

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2501 Fire Protection and Regulation

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2501.01.01 General Facts about Fire

Fire is an accident which can cause great damage on structures and injure people. In engineering, fire is an accidental load which has to be taken into consideration. It has been performed very little research work on the subject aluminium alloy structures and fire. But some facts can be stated:

- aluminium alloy structures are non combustible and will for that reason not contribute to the combustion in a fire,
- aluminium alloys melt at 580 - 660 °C,
- most aluminium alloys have lost about 50% of its original strength at 180 - 250 °C,
- aluminium alloy structures which have requirement to fire resistance, must usually be insulated.

In this part of the course we shall learn a little about fire, fire testing, fire protection philosophy, aluminium alloys at elevated temperatures, insulation materials and techniques, and fire technical design of aluminium alloy structures.

For fire to occur the following prerequisites must be fulfilled in a specific proportion:

- combustible material
- oxygen (air)
- heat

The combustible material can be:

- solids
- liquids
- gases

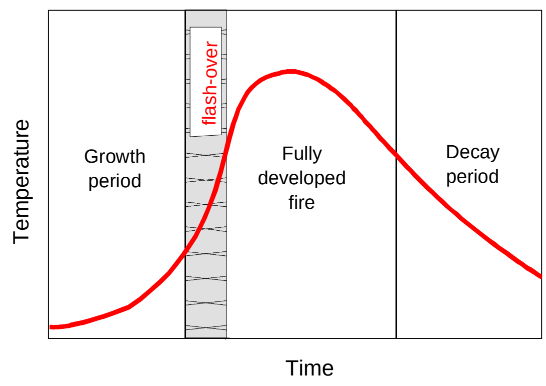
Gases having critical mixtures can ignite spontaneously when exposed to a heat source. Both liquids and solids have to be warmed up to volatilize combustible gases before they ignite. It is always a combustible gas which burns after being produced by heating combustible material.

Oxygen is needed for combustions of almost every combustible material. The oxygen content of the air is usually sufficient.

When combustible material is ignited, the fire will often produce enough heat to keep the volatilizing of combustible gases going, otherwise the fire will stop by itself. The production of combustible gases from solids is called pyrolysis. Pyrolysis requires a lot of energy and the surface temperature of burning solids must be high (more than 400 °C).

When liquids are burning, it is sufficient that combustible gases evaporate from the surface. This will happen at much lower temperatures than for solids. For many liquids evaporation takes place already at room temperature.

The flame we see in a fire is the glowing of soot particles. The glowing stops at about 540 °C and the border of the flame will have this temperature. The flame colour is dependent on the temperature distribution in the flame and the fuel.



Time-Temperature Curve for a Compartment Fire, the Fire Divided into Three Periods — 2501.01.01

As shown in **Figure 2501.01.01** a fire in a room goes through 3 phases [1]:

Phase I : Growth period

Phase II : Fully developed fire

Phase III : Decay period

During the growth period the fire is localized in the vicinity of its origin, and the average temperature of the room is low.

The transition to the fully developed fire is called "flashover" and involves a rapid spread from the area of localized burning to all combustible surfaces within the room. During the fully developed stage of a fire, the rate of heat released reaches a maximum. Flames may emerge from any ventilation opening, spreading fire to the rest of the building, either internally or externally.

The decay period is identified as the time when the average temperature has fallen to 80% of its maximum value. In this period most of the combustible material is burnt.

The temperature and the duration (the fire rate) of a fully developed fire are dependent on

- the quantity of combustible material
- the oxygen supply
- the thermal properties of the surrounding partitions

An increase in quantity of combustible material will mean an extension of the duration of the fire and a slight rise of temperature.

An increase in the oxygen supply will result in a considerably higher temperature in the compartment in fire and shorten the duration of the fire (the combustible material burns more rapidly).

With sufficient oxygen supply it will be the type and shape of the combustible material which will govern the fire rate.
The heat loss from a compartment in fire will depend on the free openings and the thermal properties of the partitions. Very good insulated partitions will conduct only small quantities of heat to the unexposed side, and the average temperature of the compartment in fire will increase.

2501.01.02 Spread of Fire

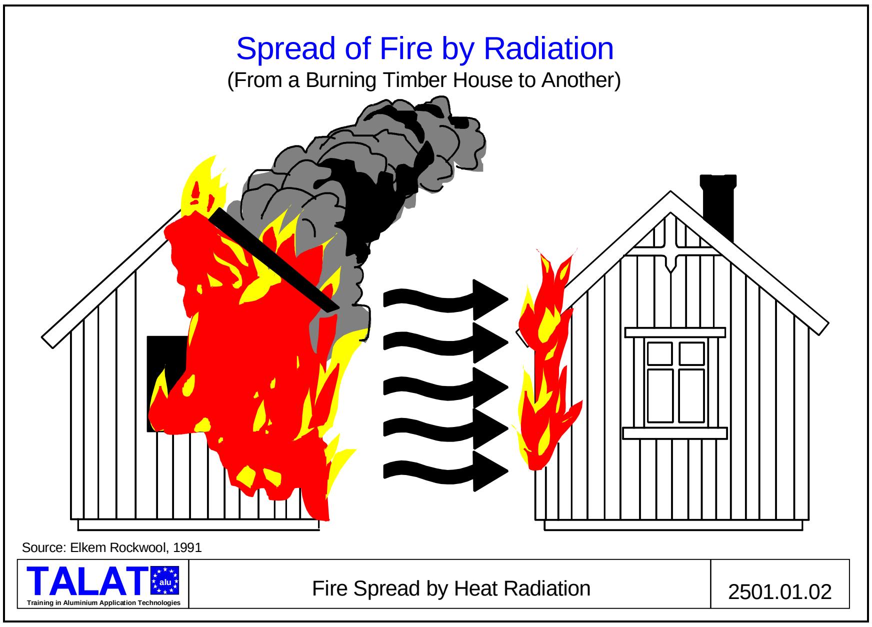
A fire can spread from its origin compartment to surrounding compartments and buildings in three ways:

- by radiation
- by conduction
- by convection

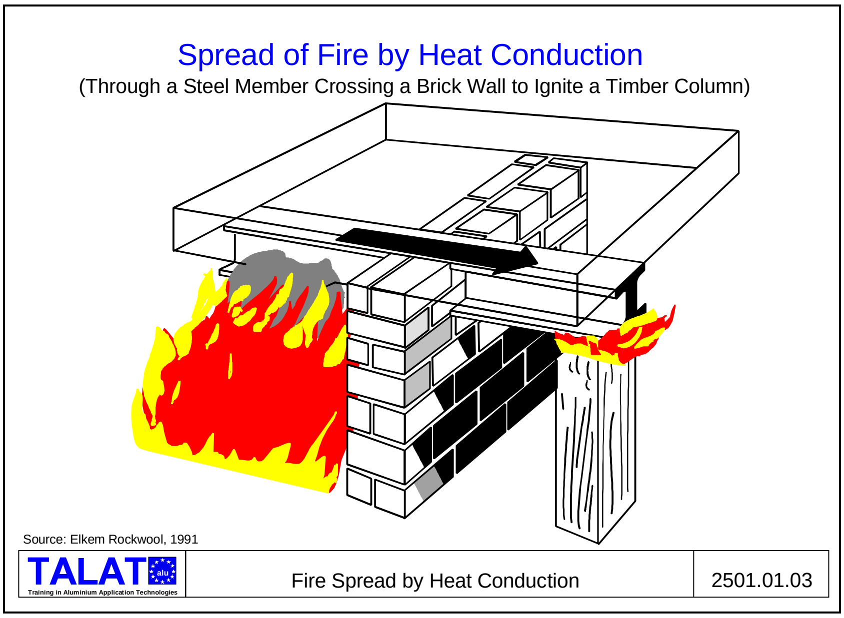
Heat radiation from a source is described by Stefan Boltzmann's law.

Heat radiation exposure to a building element or a body is dependent on the temperature of the heating source, the size of the source and the distance between the source and the exposed element or body.

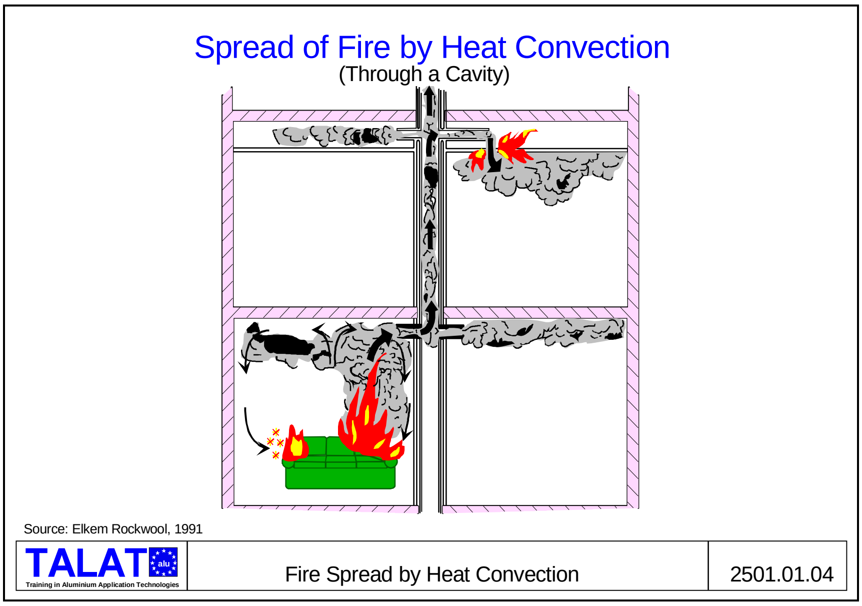
Combustible material exposed to heat radiation can ignite spontaneously. In a fire the heat radiation source can be the windows and door openings of the compartment in fire (**Figure 2501.01.02**).



The heat conduction through a partition can be so high that the temperature on the unexposed side may ignite combustible material laying close to the partition (**Figure 2501.01.03**).



In a fire confined to a compartment a lot of combustible gases do not burn because of the lack of oxygen. These hot gases will convect to other areas of the building through openings, cavities etc. Coming to areas with more oxygen these gases will ignite and burn (**Figure 2501.01.04**).



2501.01.03 Smoke and Fire Gases

Fire produces a lot of smoke and gases. Hot smoke and fire gases are lighter than cold air and for this reason will rise. In a compartment fire it will always be a layer of fresh air near the floor until the fire is extinguished and the smoke is cold.

The firegases are more or less toxic. Most fire casualties are caused by toxic gases, and particular by carbon monoxide which is the most usual toxic gas in a fire. There are, of course, more toxic gases, but they usually exist in a much lower concentration.

Hot smoke (air) is also dangerous to breath not only because of soot but also because of the high temperature. The soot deposits in the respiratory passages and hot air destroys the lungs (air temperature above 150 °C).

2501.01.04 Fire Resistance Tests

The authorities impose requirements to the fire resistance of constructions and partitions. Fire resistance is defined as:

- the time in minutes during which a construction element resists a standardized thermal load while still retaining the required characteristics. These characteristics are the loadbearing capacity and/or a separating function as a partition.

A standardized thermal load is described in ISO 834 as:

$$T - T_0 = 345 \log (8t + 1)$$

where:

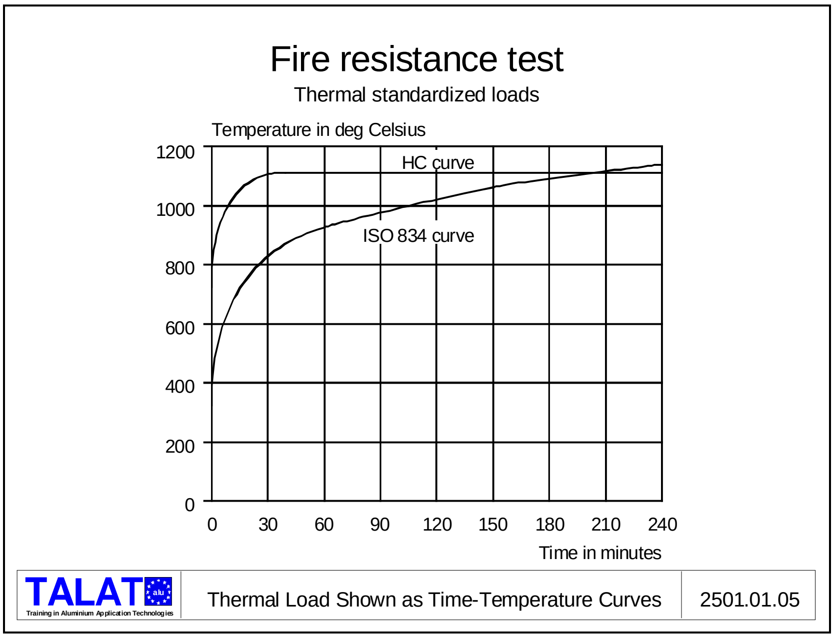
T = fire temperature in ° Celsius
T_0 = temperature at the start of the fire in ° Celsius
t = time in minutes

The oil industry in the North Sea defines another standardized thermal load, the so-called HC-fire (hydrocarbon fire) [14]. This thermal load is defined as (see also **Figure 2501.01.05**):

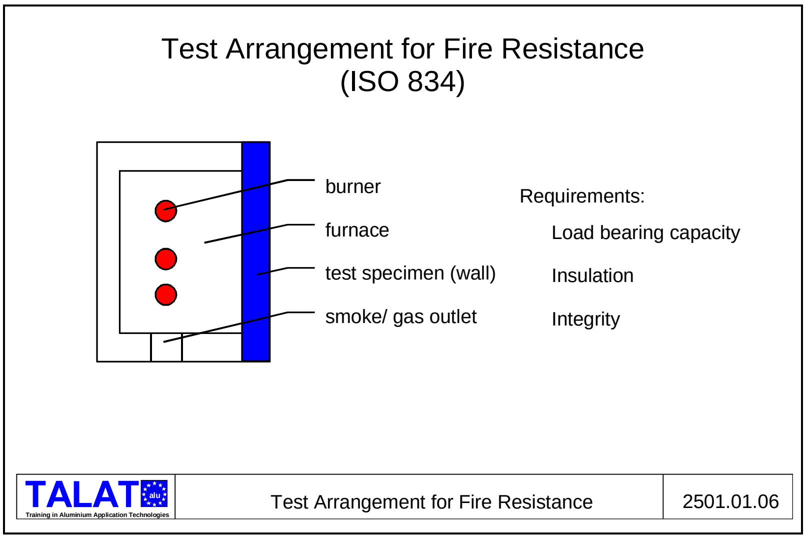
$$T_t = 1100 (1-0{,}325 \exp(-0{,}167t) - 0{,}204 \exp(-1{,}417t) - 0{,}471 \exp(-15{,}833\ t))$$

where:

T_t = fire temperature in ° Celsius
t = time in minutes



To determine the fire resistance of a construction or partition, standardized fire tests can be performed. In a fire test the specimens are put on, at or in a furnace which is capable of subjecting the test specimens to the standardized thermal load. A test procedure (**Figure 2501.01.06**) is described in ISO 834 [5].



The test specimens shall be heated in the prescribed manner until failure occurs under any one of the relevant test requirements:

load bearing capacity
insulation
integrity

– Load Bearing Capacity

For load bearing structural elements, the test specimen shall not collapse in such a way that it no longer performs the load bearing function for which it was constructed.

– Insulation

For elements of structure such as walls and floors which have a function of separating two parts of a building

- the average temperature of the unexposed face of the specimen shall not increase above the initial temperature by more than 140° C.
- the maximum temperature at any point of this face shall not exceed the initial temperature by more than 180° C and shall not exceed 220° C, irrespective of the initial temperature.

– Integrity

Initial integrity failure will be deemed to have occurred e.g. when a cotton pad is ignited or when sustained flaming, having a duration of at least 10 s, appears on the unexposed face of the test specimen.

Ultimate integrity failure should be deemed to have occurred when collapse of the specimen takes place or at an earlier time on the basis of criteria stipulated before and differing from case to case.

In the Construction Product Directive submitted by the Commission of the European Community, fire resistance is defined as an essential requirement to protect life, health and property.

The criteria by which fire resistance is assessed are the following:

- Load bearing criteria (R)
- Insulation criterias (I)
- Integrity criteria (E)

As described earlier fire resistance is related to the time in minutes during which a construction element resists a standardized thermal load while still retaining the required functions R, I, E or combinations of these.

Requirements to fire resistance for different construction elements can be:

- Load bearing column or beam : R60
  (60 mins. load bearing capacity)
- Non structural partitions: IE60
  (60 mins. resistance against high surface temperature on the unexposed side and tightness for flames, gas and smoke).

2501.01.05 Tests

There are a lot of national and international tests and procedures covering various fire resistance characteristics:

- non combustibility: ISO 1182
- limited combustibility: ISO 1716
- ignition properties: ISO 5657
- heat of combustion: INSTA 412, ISO 5660 - 1
- smoke development INSTA 412, ISO 5660 - 1
- flame spread IMO Res. A653 (16)

Several test procedures and apparatuses exist for the testing of different building elements such as cladding, flooring, ceiling, roofing, structure etc.

2501.02 Fire Protection Philosophy

- Passive fire protection
- Active fire protection

The philosophy of protecting a structure from collapse during a fire is:

– to warrant a safe escape for the people inside the structure

– to safeguard the value of the structure and its contents as much as possible

– to prevent fire from spreading to surrounding areas and buildings

To achieve these goals the authorities have imposed some requirements. These requirements are different in each country, but mainly they deal with:

- fire escape routes
- fire alarm systems
- fire resistance of structures
- fire walls and/or fire rated partitions
- the use of combustible materials
- fire extinguishing systems
- smoke control systems

The importance of these items is different for a hospital, a hotel, a factory etc. For buildings containing people, the emphasis is laid on the security of safe escape, either assisted escape or escape by oneself.

For buildings containing few people, but with a valuable content, the emphasis is laid on the security of avoiding fire spread and protecting the value.

This is illustrated in the following table:

Safe escape	Protect value	Avoid fire spread	
A	C	C	Fire escape route
A	B	C	Fire alarm systems
C	B	A	Fire resistance of structures
C	A	A	Fire walls/partitions
B	C	C	Use of combustible materials
B	A	A	Fire extinguishing
B	A	A	Smoke control
A : Stringent demands to B : Requirements to C : Minor requirements to			

2501.02.01 Passive Fire Protection

Passive fire protection of a structure means that the structure is insulated in such a way that the temperature rises in the structure and/or on the unexposed side of the structure is lower than the maximum allowable temperatures.

As insulation materials for passive fire protection of a structure, the following materials can be used:

- Rockwool
- Ceramic fibre
- Calcium silicate plates
- Vermiculite plates
- Gypsum plates
- Intumescent materials
- Spray-on cement based materials

Spray-on cement based materials will destroy aluminium's good ability to corrosion resistance and are for that reason not recommended as fire insulation of aluminium alloy structures.

Intumescent materials have to be specially tested on aluminium structures to check out the necessary thickness of the layer.

The advantage of passive fire protection systems is that the system is always intact and will act as a protection without any automatic or manual controls, and that it is easy to detect if it is destroyed.

Use of intumescent materials may be in the borderland between active and passive protection since the material has to swell out before it will act as a protection.

2501.02.02 Active Fire Protection

Active fire protection is protection which is to be activated when the fire starts.

Active fire protection can be automatic extinguishing systems, cooling systems, alarm systems, shut down systems etc.

The purpose of the active fire protection can be:

- to extinguish the fire
    - sprinkler systems
    - foam systems
    - powder systems
    - halon systems
- to bound the fire
    - smoke evacuation system
    - water curtain
- to cool equipment/structures
    - deluge systems
    - smoke evacuation system
- to alarm people/activate systems
    - detection systems
- to stop the fuel supply
    - shut down systems

Usually an automatic detection system is used together with one or more of the other systems mentioned above.

2501.03 Regulations

- Objectives
- Building regulations

2501.03.01 Objectives

The requirements for fire prevention of buildings are stated in national or regional building regulations.

The requirements usually depend on:

- the use of the building
- the height of the building
- the area of the building
- how the building is situated

In a building there are different requirements for:

- main bearing structures
- secondary bearing structures
- floors
- walls
- roofs
- staircase
- cladding
- roofing

The requirements for the cladding and roofing usually depend on the inflammability of the material. Aluminium cladding and roofing belong to the group of non-combustible materials.

For the other building elements there are requirements for fire resistance with respect to structural integrity or partitioning functions or both.

Regulations for ships, the offshore oil industry and transportation industry also contain sections about requirements for fire resistance and other technical details concerning fire prevention.

For marine applications there are several international regulations containing requirements for the use of various materials in different kinds of ships and also containing specific requirements for fire resistance of bulkheads and decks (SOLAS). Moreover, concerning the offshore oil industry e.g. Norway and Great Britain have their own regulations for fire prevention on oil platforms and oil rigs.

2501.03.02 Building Regulations

Many nations have their own building laws and regulations. The building regulations for some of the nations are listed below:

Denmark	Bygningsreglement 1982
France	Brochure No. 1477, Tomes 1 à XI, Securité contre l'incendie. Etablissements recevant du public.
Germany	TGL 10685 - Bautechnischer Brandschutz, in addition regional building regulations.
Norway	Byggeforskrift 1987
Spain	Norma basica de la edificación NBE CPI - 82. Condiciones de protección contra el fuego de los edificios
Sweden	Nybygnadsregler, BFS 1988:18, BFS 1990:28
United Kingdom	The building regulations 1985

2501.04 References/Literature

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2501.05 List of Figures