THE PRINCIPAL RISKS CAUSED BY THE FIRE

Oleg SUSAN[1], Valeriu PANAITESCU[2]

The fire which extends inside a building, and especially in ventilated or open spaces, have two distinguished phases: the fire in the first phase is checked by the fuel, and in the second phase by the disponible quantity of oxygen. In this second phase the occupants are facing major risks. In the second phase the fuel is not completed, because not all the pyrolysis products burn in the fire origin place, but spread with hot gases and smoke, existing the risk to set on fire the neighboring locations.

In the event of the incomplete burning also grows up the chemical risk too. The theoretical burning gases quantity from the specific chemical reactions of a certain burning process can be determined through stochiometric calculations. But in many cases the burning is incomplete, because the substances which interfered in chemical reactions couldn't be recognized with accuracy. The inhalation of the burning gases constitutes the principle cause in fires: the decease.

The flashover phenomenon occurs when the temperature of hot gases touches values of 600^0 Celsius, but in other cases exist a thermal unsteady situation when the flashover can occur before the value of 300^0 C. The passage to the flashover is short in comparison with other phases of the fire, sometimes being just like a snapshot, as kindling. The flashover is also a process of short standing. Once the flashover occurs, the risk for people sensibly increases because the burning phase becomes generalized, creating temperatures up to $1100\ ^0$ C.

In this time, the resistance structures and the construction elements are very affected by the fire, they can crack and fall. As the most serious risk of the firefighting teams, we must recall the back draft phenomenon.

In the event of not sufficient air quantity the burning intensity diminishes resulting two possibilities: either the fire enters in a regress phase, either a contribution of supplementary air (through the breakage of a window, the opening of doors) below the neutral plan of building, which challenged the appearance of back draft phenomenon followed by the flashover.

Keywords: fire, smoke, heat, ventilation.

1. Introduction

Fires are generated, in general, by the occurrence and development of flames which actually constitute the symbol of fire. Generated heat, smoke and burnt gases and even inadequate utilization of extinguishing products have baneful effect on people, belongings and environment.

[1] PhD Student, University "Politehnica" of Bucharest, Romania
[2] Prof., Hydraulics and Hydraulic Machinery Department, University "Politehnica" of Bucharest

Phenomenon like smoke exhalation and burnt gases are many times ignored, not being so evident dangerous like flames. Although, many times these products of burning provoke bigger hazards and destructions than flames, including death. Statistics prove that more than a half of persons who lost their lives recently in fires, died because of smoke.

Recent researches showed that the convective-radiant processes are predominant in fire propagation. Flames and hot gases are directional by pressure differences from one space to another, whether horizontal by openings (joints) or fissures around the doors, or through open doors or either vertical through pipes, tabulator, openings into ceilings and alongside the front wall through the windows and going up to the next floor.

Circulation of burnt gases and smoke inside building, on vertical or horizontal direction play a major part in fire propagation. Due to high thermal potential of burnt gases and due to existence of unburned gases as well, new burning points may occur when air excess area are reached by the fire.

2. Thermal and chemical risk embitterment during fire main phases

Generally, the fire may involve solid, liquid and gaseous fuels, but in case of a building with civil designation, we may restrict the study to solid fuels.

In case of opened fires or when the amount of existing oxygen is always sufficient to burn whole fuel by pyrolysis, indicating with *m* pyrolysis intensity or loss of mass during combustion expressed in kg/sec and with h_c – combustion heat expressed in J/kg, combustion speed is given by the expression

$$Q = mh_c \quad [\mathrm{W}]. \tag{1}$$

Combustion speed increases at the same time with increase of atmospherically temperature and pressure. When temperature increases, the oxidation speed and combustion speeds increase as well.

Combustion conditions influence combustion speed through wind direction and speed and through air stream. The combustion speed is generally lower in confined spaces and depends upon surface of fuel and openings through which gas exchange between the fired zone and outer environment. The combustion speed increases suddenly when exchange of gas increases or a high amount of air get inside (for example, by breaking a window).

In return, for the fires which develop inside buildings, in confined and ventilated spaces, we must distinguish two phases.

Initially, the amount of air is sufficient for combustion of existing combustible materials which burnt like they are in the opened air; subsequent the oxygen get diminished until it reaches the situation in which the fire is limited by the amount of available air occurs. Therefore, during the first phase the fire is controlled by materials' combustion and then, during second phase the fire is controlled by the available oxygen given by the fans.

The major risks are faced by the occupants during the second phase.

The combustion is not complete during second phase, not all pyrolysis products burn in the fire origin place, but it gets propagated together with smoke and hot gases facing the risk of spreading fire in the vicinity where the available oxygen might be found.

Chemical risks increases as well, chemical compositions suffer modifications, particularly significant emissions of monoxide carbon are generated as result of incomplete combustion. This exacerbation of thermal and chemical risks increased with decreasing of oxygen amount which maintain the combustion process.

Another phenomenon is playing a very important part in the confined spaces: re-irradiation of walls, ceiling and hot gas layers which are formed in the upper part of fired room, conducting to a feed back.

The re-irradiated amount of heat differs from a room to another according to size and thermal inertia of those (thermal inertia is defined as being the product between density of material - ρ, conduction coefficient - K, specific heat - c.

$$i = \rho K c \,. \tag{2}$$

Feed back is awarded to one of the most severe risks related to a fire in a confined space: flash over or generalized fire.

3. Risk related to flash over phenomenon or generalized fire

If the amount of air required for a fire is sufficient, the flash over phenomenon occurs.

Flash over is based on the fact that in a specific domain of temperature, the development of a fire is non-stationary, because the heat flux of radiation toward fuel increases faster than heat losses flux. While reaching the lowest temperature which is characteristic to non-stationary estate, a temperature increase might occur, the speed of increase being limited to walls and fuels thermal properties.

Due to this phenomenon the oxygen amount from air decreases suddenly, concentration of monoxide carbon reaches maximum value (up to 20%), being the most dangerous moment for firemen intervention, the atmosphere becoming lethal. In this fire critical moment, temperature increases exponential fast, and smoke generation flow rate is maximum.

Conversion into a generalized fire is short as compared to other phases of fire, being sometimes instantaneous, like firing. The flash over is also a short term phenomenon, not being a precisely event, a punctual one.

Sudden increase of combustion surfaces stimulates, for few minutes, a susceptible depletion of fuel (oxygen), similar to a backward draught, being accompanied by a vibration phenomenon and an overflow of monoxide carbon critical limit.

Subsequent to flash over phenomenon, when the combustion becomes generalized, the temperatures tend to homogenize, showing the net preponderance of radiation phenomenon. The heat flux generated by combustion reached maximum and as result high temperature could be reached, around 1100˚C.

The endurance and construction elements are most affected by the fire during this phase; they could get fissured or collapsed. Collapsing of a construction element could affect the entire enduring structure of building. Fissuring of a wall allows fast propagation of fire, by entrapping the flames in the adjacent spaces or by intensifying the heat transfer.

When the accumulation volume of smoke is high, the oxidization of smoke particles inside room increases and its generation speed is reduced. In case the openings are small, a dense smoke is generated due to delayed air afflux. The rooms nearby the generalized fire become suddenly obscure due to dense smoke and then, when ventilation permits a sufficient infusion of air it gets mixed with distillation products and it generates new fire focal points.

A risk evaluation of generated smoke inside a room can be performed by using the extension coefficient or smoke generation speed which is given by the wedge between fuel gases, including smoke particles, and density of gas.

The extension coefficient indicates smoke unitary density and it is defined starting from the expression of visibility through smoke

$$I = I_0 e^{-C_f L} \tag{3}$$

where:

I, I_0 – smoke lightness intensity, respectively without smoke;

C_f – extension coefficient

L – radiation wavelength

Out of the above equation results:

$$C_f = \frac{1}{L} \ln \frac{I_0}{I} \tag{4}$$

Smoke generation speed can be defined with the help of equation [6]

$$W_f = C_f \cdot \mu \cdot A \sqrt{2g\Delta p \cdot \rho \cdot \frac{273+t}{273}} \tag{5}$$

where: C_f – smoke extension coefficient

μ – streaming coefficient

A – gas flow streaming section, [m^2]

Δp – pressure drop, [Pa]

p – smoke density, [˚C]

It is very difficult to define exactly the transition point toward flash over, because this phenomenon does not occur through instantaneous snap, but in a limited period of time, and the behavior of various factors, such as: smoke generation, flame radiation, etc., changes at different moments of time. Being a phenomenon defined by the instability of chemical and physical processes, its comprehension into a mathematic model is difficult to be achieved.

The flash over could be considered as being a thermal instability case inside compartment. The combustion speed is function of temperature, which is limited by air supply speed. As a consequence, a quasi-stationary model of fire development could be performed; in this model a comparison between generated heat flow and heat losses flow, as a function of temperature. Thus, period of flash over is a result of fast increase of temperature and energy flux educed, based on heat losses flux. The hypothesis as per which fire development is stationary, is valid only before flash over, which may be considered being a discontinuity in the evolution of fire.

The phenomenon could be illustrated by making reference to figure 1 [1].

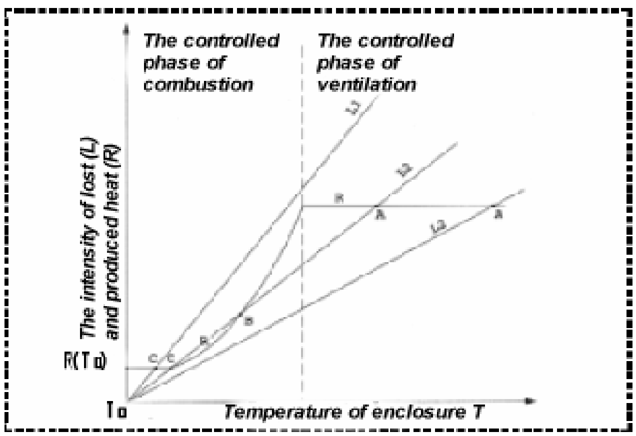

Fig. 1. Three points of equilibrium with feedback.

The heat produced by fire R and lost heat *L* are showed on the ordinate line, and the temperature of the enclosure, *T* which is showed on the abscise.

Heat R is given by the sum between heat obtained from general pyrolysis at T_0 temperature which is constant and heat generated by general pyrolysis given by the feed back which varies as per (T^4-T_0^4).

R increases in this equation until the fire gets controlled by combustion then, when it reaches the second phase of fire it does not increase at all and the generated heat does not depending upon by existing pyrolysis products, but the available amount of oxygen.

Lost heat, *L*, is the heat necessary to heat the air volume from temperature T_0 to *T* plus heat transferred from walls and ceiling and it has a route almost linear, having an angular coefficient which depends upon size and thermal inertia of walls and ceiling.

Three equilibrium points, C B A, could be noticed in figure 1. C and A are stable equilibrium points, a temperature increase being compensated by an increase of lost heat and the opposite; B is an unstable equilibrium point and if we have and increase of ambient temperature higher than B, generated heat increases immediately until reaches the stable equilibrium point A, which is the proper condition for flash over.

Obviously, because flash over occurred, it is necessary that sizes of enclosures and thermal inertia of walls to correspond to line L crossed by curve R, which represents a sufficient ventilation, even if consumed oxygen in case of flash over is minimum and if thermal load is sufficient in order to brig the ambient temperature at the necessary value.

Generally, there are some hypothesis as per which the flash over occurs when hot gases temperatures reaches 600˚C; there are also thermal instability cases in which points C and B coincide in a tangency point and flash over might occur even sooner than 300˚C (figure 2).

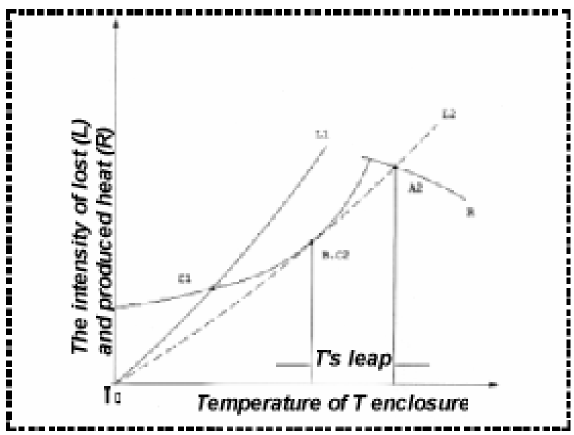

Fig. 2 . The instability obtained by reducing the quantity of last heat through walls.

In case of a sufficient ventilated compartment, the fire can develop without boundaries. A layer of hot gases and smoke, in a homogeneous mix is formed at the upper side of a room.

In case a compartment is insufficient ventilated, a dense layer is formed in which an advanced stratification may be observed.

The smoke and the hot gases post flash over, reach in combustible volatiles and monoxide carbon as result of incomplete combustion, become extremely dangerous for the adjacent spaces; in case any opening toward the adjacent spaces occurs in which enough amount of gas is available, all combustible materials met on its way are burnt at an amazing speed.

Frequent similar examples conduct to the conclusion as per which all spaces to be emptied before reaching this phenomenon.

The risk of flash over remains there for the teams which operate for extinguishing. The teams must act conscious and with maximum warning.

4. Risks of back draft

Back draft is one of the most severe risks faced by firemen brigades.

In case the amount of water is not enough, the intensity of air decreases having 2 possibilities: fire enters into regression phase or a supplementary addition of air occurs under the neutral plan of building (breaking windows and opening doors), which provoke back draft phenomenon followed by generalized fire. Back draft phenomenon has similar behavior as flash over phenomenon, meaning sudden flame propagation which extends the entire combustible surface of room, increase of temperature; reduce of monoxide carbon percentage, etc.

A back draft phenomenon may be recognized after some aspects such as: small flames less visible, excessive heat, smoke changing its color from black to grey and goes out though leakiness.

When the fire comes to oxygen deficit and proper conditions for flash over miss, in general in confined spaces with lack of ventilation, the fire tend to extinguish, but not before having an incomplete combustion with massive emissions of monoxide carbon.

Under these circumstances any opening of a door, window, and hole in a wall or in a roof, might bring addition of oxygen which may provoke instantaneously an enormous flame which could be lethal for rescuers.

5. Conclusions

The developing phase of a fire is the most important phase from rescuing of people point of view because the concentration in monoxide carbon reaches the maximum levels.

The fire cannot be practically extinguished after producing of the flash over. By knowing the proper condition for occurring the flash over, required actions could be taken.

If the fire occurs in a building, first to do is to rescue people from a fire and to leave them away from the fire origin place and ensuring the necessary times for evacuation under present circumstances.

Knowing the risks linked to a fire – it defines the available time for evacuation of inhabitants from a building and the conditions to perform required activities to extinguish the fire, these conditions being generated by the flash over or back draft phenomenon.

A correct analysis of characteristics of a building, persons and assets which exploit it, equipping with active and passive systems to protect against fire, may increase time before flash over occurs or even avoid those critical phases of a fire when the risks are maximum, thus increasing building safety during fire toward requested limits.

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