Flashover Control with Water-Based Fire Suppression Systems

V. NOVOZHILOV and J.H. KENT
Department of Mechanical and Aeronautical Engineering,
The University of Sydney, NSW 2006, Australia

ABSTRACT

The role of water sprinklers and water mist systems in prevention of flashover development in compartment fires is investigated by an analytical zone model approach. A heat balance equation for the upper hot smoke layer is analysed using the techniques of the thermal explosion theory. Two limiting cases of non-evaporation and complete evaporation are considered. An analytical model is developed to represent droplet motion and heat loss from hot layer of combustion products to non-evaporating water spray. The critical water application rate required to prevent flashover development is found as a function of spray and fire characteristics.

KEYWORDS: Fires, Flashover, Water suppression systems

NOTATION

$a_{1,2}$	model coefficients
A	surface area
A_f	fire burning area
c_p	specific heat
C_D	drag coefficient
d	droplet diameter
D	Fractional height of the inter-zone boundary
F	droplet size distribution
f	density of droplet size distribution
G	heat gains into smoke layer
H	convective heat transfer coefficients
H	height of compartment
L	heat losses from smoke layer
m	droplet mass
$\dot{m}_{out}$	mass outflow from compartment

Nu Nusselt number
Q_0 characteristic heat flux to smoke layer
q heat flux to fuel bed from fire
Re Reynolds number
t time
T temperature
U tangential velocity component of the droplet
V vertical velocity component of the droplet

Greek symbols
α emissivity
Δ smoke layer thickness
Δh_c heat of combustion
Δh_{vap} heat of vaporisation of fuel
χ efficiency of combustion
ϑ dimensionless temperature
ρ density
σ Stefan-Boltzman constant
τ dimensionless time
Ψ water discharge rate

Subscripts
0 initial
cr critical
p particle
spr spray
u upper zone
v vents

INTRODUCTION

Flashover is a stage in compartment fire development which can be described as a rapid transition from a slowly growing to a fully developed fire.

The are two scenarios which can lead to flashover. First is associated with rapid fire spread over unburned parts of fuel and subsequent sharp increase in fire power. However, flashover is also possible in situations where fire burning area does not change significantly. The underlying mechanism in this (second) scenario is essentially a positive feedback from fire environment to the burning fuel. Formation of hot ceiling layer at the early stages of fire leads to radiative feedback to the fuel, which, in turn, results in an increase of the burning rate and the temperature of the smoke layer. If heat losses from the compartment are insufficient, then a sharp increase in the fire's power (i.e. flashover) will eventually occur.

Theoretically, flashover has been studied by both analytical and Computational Fluid Dynamic (CFD) approaches. Luo et al. [1,2] demonstrated that detailed CFD modeling can predict flashover development in a complicated multi-room geometry. The application of field modeling to flashover is, however, still a difficult task because of strict computational requirements on the accuracy of radiation modeling and the lack of reliable models of flame spread over various solid fuels. Disadvantage of CFD approach is that it is only applicable to a particular physical configuration.

On the other hand, flashover can be theoretically analysed using zone modelling of fire along with the methods of non-linear dynamics. Early attempts to investigate thermal instabilities, which may be interpreted as flashover, were made by Thomas [3,4]. Further investigations of flashover by methods of non-linear dynamics [5,6] have revealed a nature of bifurcations which represent flashover in a space of appropriate controlling parameters.

The mechanism of positive non-linear feedback makes flashover phenomenon similar in many respects to the classical thermal explosion theory. This analogy has been used [7,8] to develop an analytical approach to the prediction of critical conditions for flashover.

Early in fire development the combustion products are usually segregated in a well-stirred ceiling layer with roughly homogeneous properties. For this reason, zone models are able to achieve reasonably good qualitative and quantitative agreement with experiments, as has been demonstrated in [6]. They also provide valuable analytical solutions which clearly identify the important physical effects and have general meaning, in contrast to the case-oriented field model results.

However, there is still little information on flashover development in the presence of fire suppression systems. It is clear that even if sprinkler or water mist system cannot suppress the fire completely, it can restrict fire growth and prevent flashover due to cooling of the hot smoke layer. Therefore, the effect of sprinkler operation on flashover is of significant interest for fire safety.

Preliminary considerations of this effect by means of zone modeling have been made by Novozhilov and Kent [9]. In the present study an analytical model is developed to predict effect of water-based fire suppression systems on flashover development. A more sophisticated approach, compared to [9], is taken to model water droplets motion through the smoke layer, which results in more accurate estimations of critical water application rates. An additional case of very fine water mist is also considered in the present study. The critical conditions for flashover are obtained as a correlation between fire characteristics and sprinkler discharge rate. The results are generalised for arbitrary droplet size distributions.

FLASHOVER ZONE MODEL AND RELATION TO THE THERMAL EXPLOSION THEORY

In the most general form the flashover zone model has been developed in [7]. In an enclosure with one opening, flashover is principally described by four stages. The hot buoyant plume develops at the first stage following ignition, and then reaches the ceiling and spreads as a ceiling jet (second stage). During third and fourth stages the hot layer expands and thickens, and rearrangement of the flow through the opening takes place.

During the second stage a well-stirred layer of combustion products is formed, and a zone approach may be applied. Under this approach, the compartment may be divided into two layers which are represented by average temperatures T and T_0 (Fig. 1). Flashover is assumed to happen during the initial, fuel-controlled stage of fire, so that the temperature of the lower layer may be assigned an ambient value. Few other assumptions are listed in [7].

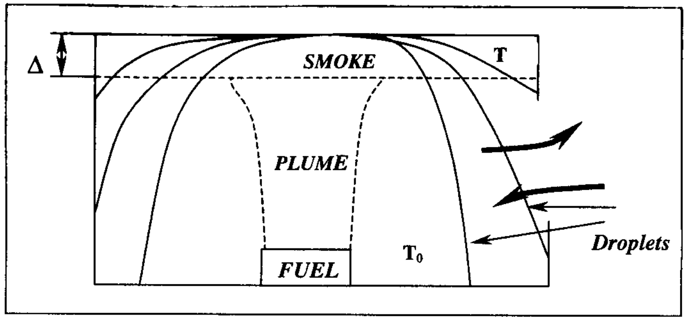

FIGURE 1 Schematic of the zone model

Application of zone modeling involves the consideration of the heat balance equation for the upper hot smoke layer which is

$$mc_p\frac{dT}{dt}=G-L \tag{1}$$

where t is time, m, c_p and T are mass, specific heat and temperature of the smoke layer, respectively. The functions G and L on the right hand side describe heat gains and losses from the layer.

In the absence of water spray, the right hand side should generally include the terms corresponding to the rates of heat gain to the smoke layer and heat losses due to outflow through the opening and due to convective and radiation losses to the walls and fuel. In the present study we only consider the case of large thermal inertia of compartment walls, which implies that the time scale for the wall heat-up is much larger than that for the flashover. This assumption is not restrictive as it retains all the major effects in the system behavior while removing unnecessary analytical complications. The cases with low and intermediate thermal inertia may be considered without significant difficulty [7,8].

The equation (1) is non-dimensionalised based on the ambient temperature T_0, characteristic heat flux (per unit time) to the upper layer Q_0

$$Q_0=\chi A_f q''\Delta h_c/\Delta h_{vap} \tag{2}$$

and the characteristic time of heating of the upper layer

$$t_*=mc_pT_0/Q_0 \tag{3}$$

In dimensionless variables the equation (1) for the case of large thermal inertia of compartment walls is reduced to [7]

$$\frac{d\vartheta}{d\tau}=1+a_1(\vartheta^4-1)-a_2(\vartheta-1) \tag{4}$$

The model coefficients $a_{1,2}$ are determined by the fire physical and geometrical parameters:

$$a_1=\chi\frac{\Delta h_c}{\Delta h_{vap}}\alpha_U\sigma A_fT_0^4/Q_0-\alpha_g\sigma\left[A_t+(1-D)A_V-A_f\right]T_0^4/Q_0$$

$$-\alpha_g\sigma A_fT_0^4/Q_0-\alpha_g\sigma\left[A_U-(1-D)A_V\right]T_0^4/Q_0 \tag{5}$$

$$a_2=\left[A_U-(1-D)A_V\right]h_cT_0/Q_0+(1-D)A_Vh_rT_0/Q_0+m_{out}(1-D)A_Vc_pT_0/Q_0$$

and have clear physical meaning. The first coefficient describes the rate of net heat gains into the smoke layer due to radiation.

Parameter a_2 characterises the net convective heat losses from the hot layer which occur due to outflow through the opening and the heat exchange between the smoke and cold surroundings.

The problem of flashover resembles the classical thermal explosion theory because in the both cases the system behavior is essentially determined by competition between heat gains and losses. The equation (4) can be investigated by similar techniques which are well developed in the thermal explosion theory [7].

In general, there may exist three solutions of the heat balance equation (1). The stable solutions represent fuel-controlled and ventilation-controlled fires. The third solution is unstable, and small perturbations around this point will result in a large change of temperature. The critical conditions for flashover existence are determined by

$$G(\vartheta_*)=L(\vartheta_*)\ ;\ \frac{dG}{d\vartheta}(\vartheta_*)=\frac{dL}{d\vartheta}(\vartheta_*) \tag{6}$$

It easily follows from equation (4) that the critical conditions are written in the following form

$$a_1(\vartheta_*^4-1)-a_2(\vartheta_*-1)+1=0\ ;\quad 4a_1\vartheta_*^3-a_2=0 \tag{7}$$

These two equations determine critical boundary in the plane (a_1,a_2) in the parametric form

$$a_1=\left(3\vartheta_*^4-4\vartheta_*^3+1\right)^{-1}\ ;\quad a_2=4\vartheta_*^3\left(3\vartheta_*^4-4\vartheta_*^3+1\right)^{-1} \tag{8}$$

where the critical temperature ϑ_* serve as a parameter. The critical curve separates regions of parameters representing flashover and low intensity fire (Fig. 2).

SPRINKLER INTERACTION WITH THE SMOKE LAYER

Activation of fire suppression system will have effect not only on fire suppression, but also the possibility of flashover in the case where fire is not fully suppressed. In the case of sprinkler / water mist system, the primary effect on flashover development will be cooling of the smoke layer and subsequent reduction in the radiative feedback to fuel.

We consider a situation where the sprinkler / water mist system fails to suppress fire directly (e.g. due to obstruction to direct action of the spray on fuel or low momentum of the spray), and therefore its only influence on fire development is through absorption of heat from combustion products.

The net heat loss to the spray would be determined by heat-up and the mass loss rates of single droplets and their residence times within the hot layer.

We consider the interaction of a sprinkler spray with the hot layer of thickness Δ and temperature T (Fig. 1) and assume uniform heat absorption into the spray within the layer. This assumption is reasonably accurate if the width of the spray is comparable with the length scale of the fire burning area, or if a number of water suppression systems are operating simultaneously over a large fire area.

The activation temperatures for suppression systems are usually low compared to typical critical flashover temperatures, so the activation times are assumed to be zero in the present study.

In the presence of a water spray there will be additional heat loss from the smoke layer. The problem can be analysed analytically in the two limiting cases, as will be shown below. These limits corresponds to the purely convective heat loss to the spray and complete evaporation of water mist. The intermediate case is likely to require numerical approaches. However, simple analytical models developed in the present study give a good indication of water application rates required for the control of flashover.

RESULTS AND DISCUSSION

Coarse Spray (Non-evaporation) Limit

As has been shown in [10], the heat transfer between the smoke layer and a water spray from a conventional sprinkler is predominantly convective.

The total heat absorption by a single droplet of diameter d in the absence of evaporation can be represented as

$$Q_{spr} = \frac{4}{3}\pi (d/2)^3 \rho_p C_p (T_\Delta - T_0) \tag{9}$$

where ρ_p is the density and C_p is the specific heat of water. The temperature T_0 is the initial droplet temperature; T_Δ is the temperature of droplets at the exit from the smoke layer.

In order to calculate the heat loss to water spray Q_{spr}, it is necessary to solve the equations of motion and heat transfer for a single droplet. Since we assume that no evaporation takes place, the mass of the droplet does not change and the dynamic and heat transfer problems for the droplet can be solved separately.

The analytical solution for the droplet motion has been obtained in [9] using the laminar expression for the drag coefficient. Such approach underestimates the drag in the range of Reynolds numbers which are relevant for the sprinklers. More accurate approach is developed in the present study, as demonstrated below.

The general equation of the droplet motion through a quiescent environment (neglecting forces other than drag) may be written as a following set of the two equations for the velocity components [11]:

$$m\frac{dU}{dt} = -\frac{\pi}{8} d\rho C_D \sqrt{U^2+V^2}\,U \;; \quad m\frac{dV}{dt} = -\frac{\pi}{8} d\rho C_D \sqrt{U^2+V^2}\,V + mg \tag{10}$$

For a typical conventional sprinkler the Volumetric Mean Diameter is of order of *1* – *2* mm. Taking the characteristic droplet size as *1* mm, Reynolds particle number for the droplets exiting orifice at velocities of 10 – 20 m/s may be estimated as Re ~ 700 – 1500. In this range drag coefficient for spherical particles is a weak function of the particle Reynolds number [11] and varies between *0.47* and *0.6*. Therefore, it may be represented by a constant value with sufficient accuracy.

Obviously, even with the constant drag coefficient the above equations are still coupled with each other. However, since droplets hit sprinkler deflector, their vertical velocity may be assumed to be small compared to the tangential velocity. Since the drag coefficient is assumed to be constant, then in the case $V << U$ the equations (10) become decoupled and may be solved separately.

The system (10) is simplified as follows:

$$m\frac{dU}{dt} = -\frac{\pi}{8} d\rho C_D U^2 \;; \quad m\frac{dV}{dt} = -\frac{\pi}{8} d\rho C_D UV + mg \tag{11}$$

The first equation contains only the tangential component, and has the following solution

$$U = \left(\frac{1}{U_0} + \frac{\pi}{8m} d^2 \rho C_D t\right)^{-1} \tag{12}$$

Substitution of this solution to the second (V – component) equation yields

$$m\frac{dV}{dt} = -\frac{\pi}{8} d\rho C_D \left(\frac{1}{u_0} + \frac{\pi}{8m} d^2 \rho C_D t\right)^{-1} V + mg \tag{13}$$

Solution of this equation is written in the following form

$$V = \frac{\kappa\left(V_0 - \frac{g}{2}\kappa\right)}{t+\kappa} + \frac{g}{2}(t+\kappa) \tag{14}$$

where

$$\kappa = \frac{4}{3C_D}\frac{\rho_p}{\rho}\frac{d}{U_0} \tag{15}$$

Since the droplet position in vertical direction is determined by

$$z = \int_0^t V(s)ds \tag{16}$$

the following equation is easily derived to estimate droplet exit time t^* from the smoke layer

$$\kappa\left(V_0 - \frac{g}{2}\kappa\right)\ln\left(1+\frac{t^*}{\kappa}\right) + \frac{g}{4}t^*\left(t^* + 2\kappa\right) = \Delta \tag{17}$$

The thickness of the smoke layer is expressed through the fractional height of the thermal discontinuity plane, D, and the height of compartment, H: $\Delta = (1-D)\cdot H$.

The heat transfer equation for the droplet heat-up may be written as

$$\frac{4}{3}\pi(d/2)^3\rho_p C_p \frac{dT_d}{dt} = \frac{kNu}{d}\pi d^2(T - T_d) \tag{18}$$

Nusselt number is a rather weak function of Reynolds number (Nu ~ $Re^{1/2}$ [11]) and may be represented with sufficient accuracy by its constant average value.

Droplet heat-up until the moment when droplet exits the smoke layer is obtained from equation (18)

$$T_\Delta - T_0 = \left[1 - \exp\left[-\frac{6kNu}{\rho_p C_p d^2}t^*\right]\right]\cdot(T - T_0) \tag{19}$$

Expressions (17) and (19) allow the calculation of heat loss to the spray according to (9).

Any spray is characterised by the droplet distribution function $F(d)$, i.e. $F(d)$ is the mass fraction of droplets with diameters smaller than d. Using (9), the total heat loss to the spray can be written in terms of the distribution density function $f(d) = F'(d)$ as

$$Q_{spr} = \Psi c_p \int_0^\infty f(s)(T_\Delta - T_0)ds \tag{20}$$

where Ψ is a sprinkler discharge rate.

Taking into account the temperature change along the droplet trajectory (19), the heat loss rate (20) is rewritten as

$$Q_{spr} = \Psi c_p \int_0^\infty f(s)\left[1 - \exp\left[-\frac{6kNu}{\rho_p C_p d^2}t^*\right]\right]ds\cdot(T - T_0) \tag{21}$$

Since heat loss to water spray is proportional to the temperature difference between the smoke layer and environment, the general temperature history equation (4) has the same form in the presence of sprinkler, but with the modified convective heat loss coefficient:

$$\frac{d\vartheta}{d\tau} = 1 + a_1(\vartheta^4 - 1) - A_2(\vartheta - 1) \tag{22}$$

The expression for the modified convective heat transfer coefficient follows from (21) immediately

$$A_2 = a_2 + \frac{\Psi c_p T_0}{Q_0}\int_0^\infty \left[1 - \exp\left[-\frac{6kNu}{\rho_p c_p s^2}t^*(s)\right]\right]f(s)ds \tag{23}$$

The transition from flashover to low intensity fire due to water discharge by sprinkler may be interpreted in the plane of governing parameters (a_1, a_2), as shown in Fig. 2.

Suppose the coefficient a_1 is fixed and the system is initially in the flashover area (Fig. 2). As water discharge rate (and the coefficient a_2 correspondingly) increases, the point (a_1, a_2) moves to the right until it crosses the flashover boundary at some critical value of a_2.

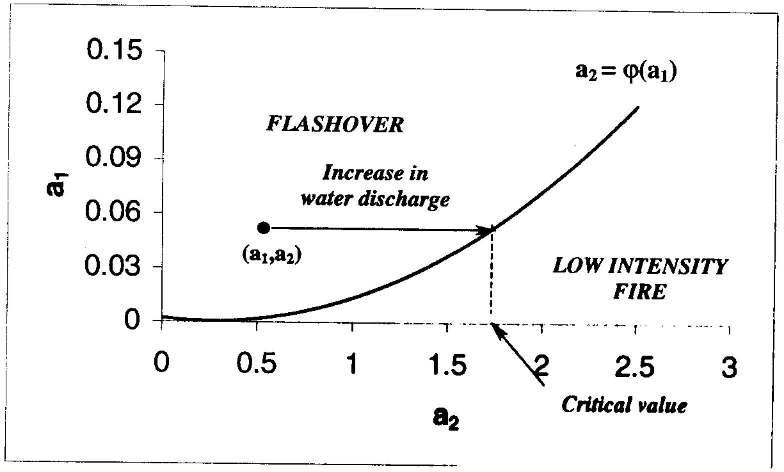

FIGURE 2 Flashover critical boundary and effect of water discharge rate

The critical water discharge rate will depend on the distance between the point (a_1,a_2), representing the initial parameters, and the critical curve which we denote as $a_2 = \varphi(a_1)$.

The critical sprinkler discharge rate to prevent flashover is therefore given by

$$\Psi_{cr} = \frac{Q_0}{c_p T_0}\left[\int_0^\infty \left[1-\exp\left[-\frac{6kNu}{\rho_p c_p s^2} t^*(s)\right]\right] f(s)ds\right]^{-1} \cdot (\varphi(a_1)-a_2) \qquad (24)$$

The expressions (5) for the coefficients a_1,a_2 allow the critical water application rate to be determined as a function of any geometrical and physical parameters of the fire.

Fine Spray (Water Mist) Limit

Very fine water mist may be expected to evaporate completely in the hot smoke layer. Results of CFD simulations [12] show that this is generally the case for the droplets with the diameters $d \le 0.1$ - 0.2 mm. In fact, water mist systems often fail to deliver mist into the burning region and suppress fire. However, they may be able to prevent flashover. In this case, the opposite limit (complete evaporation) is achieved.

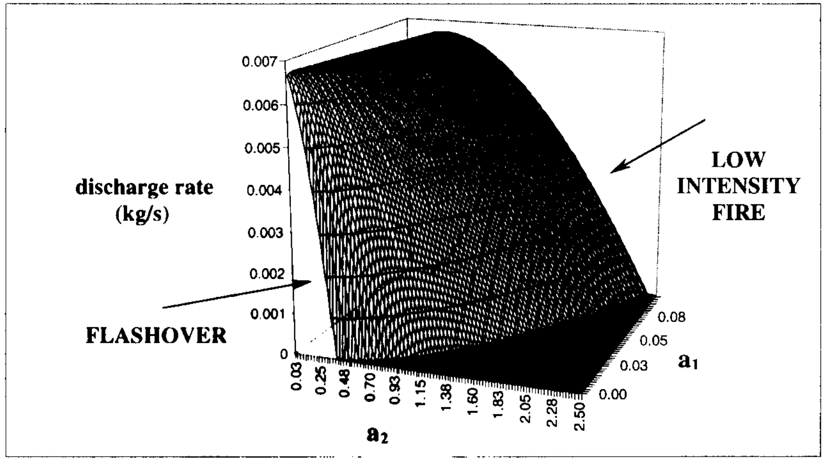

FIGURE 3 Critical surface for flashover in the case of water mist system

Assuming total evaporation, the temperature history equation takes the form

$$\frac{d\vartheta}{d\tau} = 1 + a_1(\vartheta^4 - 1) - a_2(\vartheta - 1) - \gamma\Psi \qquad (25)$$

where the additional heat sink is proportional to the water application rate and the parameter γ is defined as

$$\gamma = \frac{c_p(T_b - T_0) + H_{fg}}{Q_0} \qquad (26)$$

The critical conditions (7) are written in this case as follows

$$a_1(\vartheta_*^4 - 1) - a_2(\vartheta_* - 1) + 1 = \gamma\Psi \; ; \quad 4a_1\vartheta_*^3 - a_2 = 0 \qquad (27)$$

from which the following expression for critical water application rate follows:

$$\Psi_{cr} = \gamma^{-1}\left[a_1\left(\left(\frac{a_2}{4a_1}\right)^{4/3} - 1\right) - a_2\left(\left(\frac{a_2}{4a_1}\right)^{1/3} - 1\right) + 1\right] \qquad (28)$$

The critical conditions may be interpreted in the space of the three independent parameters (Ψ, a_1, a_2), rather than on the plane as it is the case for freely burning fire. The equation (28) determines the critical surface in that space shown in Fig. 3. The flashover area is below the surface (between the critical surface and the plane (a_1,a_2)). Above the surface the flashover is impossible. The critical surface intersects with the (a_1,a_2) plane exactly by the critical curve $a_1 = \varphi(a_2)$.

Example of Calculation of the Critical Flashover Conditions

In order to estimate the influence of a sprinkler, consider the example given in [7] for the fire with the heat release rate of 155 KW/m^2 and the radius of burning area of 0.15 m. Compartment dimensions for this case are $0.4\ m$ x $0.4\ m$ x $0.4\ m$. Fractional height of the thermal discontinuity plane is taken as 0.5. Other relevant parameters may be found in [7]. Controlling parameters can be calculated as $a_1 = 0.018$; $a_2 = 0.47$. Equation (4) gives the flashover time of 21.2 s [7].

In the case of non-evaporation limit, the critical value of a_2 is required. This value has been found in [7] to be $A_2^* = 0.49$. Assuming the uniform droplet diameter in the spray of 400 μm, the minimum water flow rate required to prevent flashover would be, according to (24), $\Psi_{cr} = 0.23\ kg/s$. This value is lower than previously estimated [9] due to more accurate representation of droplet motion in the present study.

In the case of full evaporation, the critical value of Ψ is found directly from (28) to be $\Psi_{cr} = 5.3 \cdot 10^{-3}\ kg/s$. As expected, water mist (if evaporated uniformly through the smoke layer) is most effective in the prevention of flashover. It should be noted, however, that non-evaporation case provides the upper limit for the critical water application rate. For most real sprays, the critical rate will be between the two limiting cases. Therefore, the analytical models developed in the present paper provide the upper and lower limits for any real suppression system.

In both limits the critical discharge rate is much less than used in real operations of sprinklers and water mist systems, which suggests that fire control is achievable with much more economic water supply rates.

CONCLUSIONS

An analytical model has been developed for the estimation of the critical conditions for flashover during application of water-based fire suppression systems. Two limiting cases of spray behavior (purely convective heat transfer and complete evaporation) have been considered. It has been shown that the equations of droplet motion and heat transfer can be solved analytically with sufficient accuracy in the case of convective heat loss and predominance of tangential velocity.

The minimum water flow rate required to prevent flashover has been found as a function of droplet size distribution in the spray and fire geometrical and physical parameters. Critical water discharge rate in the case of water mist system is approximately 40 times less than that for a conventional sprinkler. In both regimes the amount of water required to prevent flashover is significantly less than delivered by commercial fire suppression systems under regular operating conditions.

REFERENCES

1. Luo, M. and Beck, V., "A Study of Non-flashover and Flashover Fires in a Full-scale Multi-Room Building", Fire Safety Journal, 26, 191-219, 1996.
2. Luo, M., He, Y. and Beck, V., "Application of Field Model and Two-Zone Model Flashover Fires in a Full-scale Multi-Room Single Level Building", Fire Safety Journal, 29, 1-25, 1997.
3. Thomas, P.H., "Fires and Flashover in Rooms – A Simplified Theory", Fire Safety Journal, 3, 67-76, 1980/81.
4. Thomas, P.H., "The growth of fire – ignition till full involvement", in Combustion Fundamentals of Fire, ed. G. Cox, pp. 273-328, Academic Press, London, 1995.
5. Bishop, S.R., Holborn, P.G., Beard, A.N. and Drysdale, D.D. "Nonlinear Dynamics of Flashover in Compartment Fires", Fire Safety Journal, 21, 11-45, 1993.
6. Holborn, P.G., Bishop, S.R., Drysdale, D.D. and Beard, A.N., "Experimental and Theoretical Models of Flashover", Fire Safety Journal, 21, 257-266, 1993.
7. Graham, T.L., Makhviladze, G.M. and Roberts, J.P., "On the Theory of Flashover Development", Fire Safety Journal, 25, 229-259, 1995.
8. Graham, T.L., Makhviladze, G.M. and Roberts, J.P., "The Effects of the Thermal Inertia of the Walls upon Flashover Development", Fire Safety Journal, 32, 35-60, 1999.
9. Novozhilov, V. and Kent, J.H., "Effect of Sprinkler Operation on Flashover Development of Compartment Fires", 1999 Australian Symposium on Combustion and The Sixth Australian Flame Days, The University of Newcastle, pp. 175-179, 1999.
10. Kung, H.C., "Cooling of Room Fires by Sprinkler Spray", ASME Transactions – Journal of Heat Transfer, 99, 353, 1977.
11. Faeth, G.M., "Evaporation and Combustion of Sprays", Progress in Energy and Combustion Science, 9, 1-76, 1983.
12. Novozhilov, V., Moghtaderi, B., Fletcher, D.F. and Kent, J.H., "Numerical Simulation of Enclosed Gas Fire Extinguishment by a Water Spray", Journal of Applied Fire Science, 5(2), 135-146, 1995-96.

The New Approach to Determination Fire-Extinguishing Concentrations of Gas Compositions.

A.N. BARATOV, S.G. TSARICHENKO, A.F. ZHEVLAKOV, I.V. TIMOFEEV and R.A. YAJLIYAN
All Russian Scientific Research Institute for Fire Protection
143900, Balashiha-3, Moscow Region, Russia

ABSTRACT

The article is discussing methods of extinguishing concentration (EC) determination of gas compositions which intended for volumetric fire suppression. The article marked, that the "cup burner" method appears to be insufficiently objective and universal. This fact indicates, that in case of using this method we always receive overstated EC value in comparison with real conditions of fire suppression. The article offers a more objective way of EC determination that is the "cylinder" method which is based on introduction of the cup with a fire hearth in prepared environment. The EC value is determined as relation between extinction time and EC value. We made analytical research of accumulation process of extinguishing substance in reaction zone of diffusion flame. The accumulation is made by its diffusion transfer from environment. From the results of our research we determined an extinction time equalled 10 seconds. The EC value determines from the diagram "extinction time – EC". After processing of the results we have the following: EC for 23 halon is 8.5 % vol and for halon 125 - 7.3 %vol.

KEYWORDS: extinguishing concentration, "cup burner" method, "cylinder" method, extinction time.

INTRODUCTION

Today many countries conduct studies in order to find new "clean" agents of fire extinguishing systems, which can be alternative to brom-containing halons. Moreover it is very important to get adequate values of fire-extinguishing concentrations of these agents, which will be in conformity with the real conditions of volumetric fire extinguishing. There are two methods of determination of fire-extinguishing concentrations (EC): 1) "cup burner" method (in many countries it was adopted as standard [1]); 2) "cylinder" method. "Cup burner" method is in influence of air flow, with additions of fire-extinguishing substances, on flame of burner with heptane. "Cylinder" method [2] is in creation certain fire-extinguishing environment in hermetic cylindrical vessel of 50 l volume and bringing source of fire (small crucible with burning heptane) in this environment. To our opinion, "cup burner" method is not enough adequate for real conditions of fire extinguishing. Typical dependence of fire-extinguishing