CRITERIA FOR EVALUATION OF EMERGENCY FIREFIGHTING IN TRANSPORT TUNNELS

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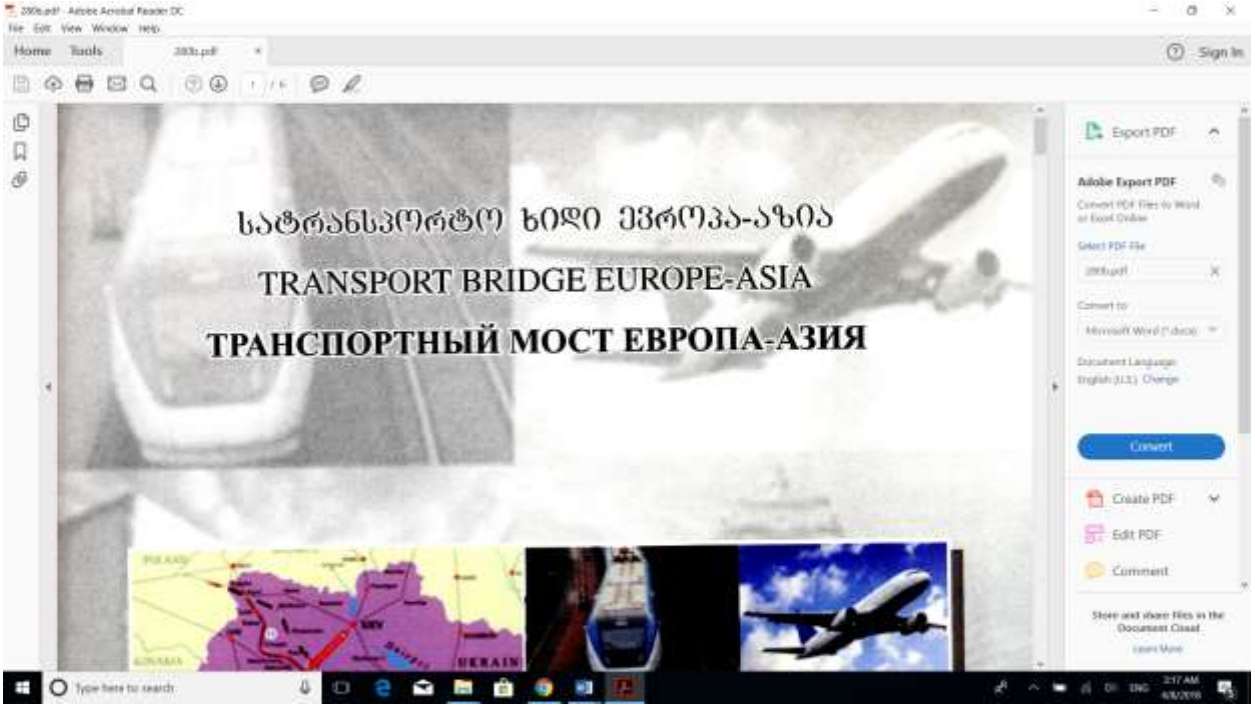

CRITERIA FOR EVALUATION OF EMERGENCY FIREFIGHTING IN TRANSPORT TUNNELS

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Summary. The criteria for the evaluation of emergency in transport tunnels during a fire are proposed. Criterion derived from the spatial and temporal scales of the development of fire. Novelty consists in the possibility of forecasting the rapidly changing situations in a fire, which in turn is described by means of CFD simulation of this process. The transport tunnel represented as complex engineering structure distributed on the space at one direction in which is the disperse vehicle stream. This fact determines a specific nature of emergency management in tunnels - management in tight spaces. The paper discusses the issues of saving the life and health of people, the relevance of this issue beyond doubt. Solution of the problem is based on the determination of risk of fires due spatial - temporal development of a fire under conditions of high dynamic of accompanying turbulent processes. The

delineation of hazardous areas is implemented by the following factors - the localization of fire, power of fire, burning rate, temperature, amount of toxic combustion products and their concentration.

1. INTRODUCTION

Motor vehicle is the most rapidly expanding sector among the modern transport infrastructure. The road communications have been growing steadily, both by the reconstruction of existing transport routes and by the constructing of new highways. The expansion of the road network is accompanied by increasing of the network transport tunnels. There is a tendency of enlarging length of the road tunnels. Obviously in such circumstances for the transport tunnels is particularly acute getting question of assessment and management of emergencies resulting from influence of the fire. It is required to begin operational and adequate measures to prevent or minimize of expected damage during of fire. Before is need to have a reliable forecast of the situation of the spatial distribution of temperature fields in the underground space.

The main component of the potential harm caused by fires are human victims or deterioration their health.

The article suggests criterion by which are possible to evaluate a emergency situations in tunnels caused by fire. These criterion on the one hand will characterize the transformation of the environment under the earth in according of spatial and of temporal scales and on the other hand will contribute to the effective management of emergencies.

Strong fires already having place in the tunnels around the World clearly have demonstrated the problem of elaboration of similar criterion. The matter is that in part of tunnels people have survived by chance while in the St. Gotthard tunnel, also in tunnel of Mont Blanc, tunnel of Frejus and elsewhere were human victims [1, 2]. Question of strong fires in traffic tunnels wasn't considered in due course in our opinion and only this work is suggested a new criterion. None the less, the incidents of fire in many of the tunnels around the World has indicated that fires in tunnels are hotter, are last longer in time, and are more destructive than on the surface.

2. STATEMENT OF A QUESTION

To assess the risk of fire, depending on its development along the length of the tunnel, this paper takes necessity to divide the tunnel into virtual spatial zones. Establishing the boundaries of each zone, or the definition of its spatial scale is carried out by taking into account the effect of injurious factors, taken into account their importance and intensity. From our point of view during fires, among other factors, the key factors are both the spatial distributions of temperature fields and of toxic products of combustion processes. The dynamics of these processes - release and dispersion of heat and toxic products is result of development of the combustion processes in time.

It is clear that during the dividing into zones the determinative should be the quality of state of person's health and the assessing could be use the recognized rankings - 5-tiered rate [3], which is presented in Table 1. These results should be consistent with adequate scenarios of fire in tunnels.

Table 1

Dividing of emergencies of space and time zones with consideration of damage

No	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
The spatial scale of each area, m	Linear length of the zone - L_1	Linear length of the zone - L_2	Linear length of the zone - L_3	Linear length of the zone - L_4	Linear length of the zone - L_5
The time scale, min.	$T_1<T_p$	$T_1<T_2<T_p$	$T_2<T_3<T_p$	$T_3<T_4<T_p$	$T_4<T_5<T_p$
The extent of damage	Hardest	Heavy	Average	Weak	Negligible

Table 1 gives the following values: The linear dimensions of the fire from the tunnel line in both directions: L_1; L_2; L_3; L_4; L_5; The determination the time of occurrence of the harm - the time scale: T_1; T_2; T_3; T_4; T_5; T_{peak}; Damage assessment: The hardest - the result is lethal; Heavy - health is not fully restored; Average - health restored as a result of treatment; Weak - health restored as a result of short-term treatment; Negligible - with the help of primary health will be restored.

Traffic tunnel is presented in the form of an elongated engineering construction with limited dimensions in space, in which takes place movement of the dispersed transport stream. This fact determines the specificity of emergency management - action in a confined space.

Statement of the problem for assess the emergency requires consideration of substantial factors of fires in tunnels as well as the phenomenological data and existing standards. For example, the recommendations of the United Nations Economic Commission for Europe notes that tunnels ventilation modes should be calculated in terms of the functioning during the fire at least 30 MW of power at temperatures of $600^0 K$.

The process of burning of vehicle, in our opinion, to be considered a priori for the most aggravating case of an emergency. For example, an emergency situation will be worse when a fire broke out in the middle of the tunnel in the absence of natural and mechanical ventilation. Obviously, that the spatial and temporal scales of other lighter ventilation mode can also be described using the appropriate initial and boundary conditions.

3. ANALYSIS

The present study was based on the statistics of heat release from automobile fire tests, during that the fire power was not more than 5 MW [4]. For the analysis were used results of the peak and the total heat release rate. According to the European Commission of the UN such fires are placed on the first stage of ranking. (see table 2).

Table 2

Quantity of the heat rate during a fire in the traffic tunnel in according of a vehicle type

Vehicle type and quantity	Quantity of a fire, MW
1 passenger car	5
2-3 passenger cars or 1 mini-bus	8-15
1 small truck	15-20
1 bus or 1 truck with non-dangerous goods	20-30
1 loaded trailer	100
1 tanker with petrol	200-300

The above-mentioned statistics were analyzed for the rising phase of fire. For the analysis of the spatial distribution of the heat flux values were considered the average mass loss of the vehicle. This is due to the conclusions of work [5], which states that the time needed to evacuate people from the tunnels, cannot be greater than the rising phase of the fire.

Fig. 1 shows the change in thermal energy of a vehicle fire, according to the results in experiments of natural terms [4].

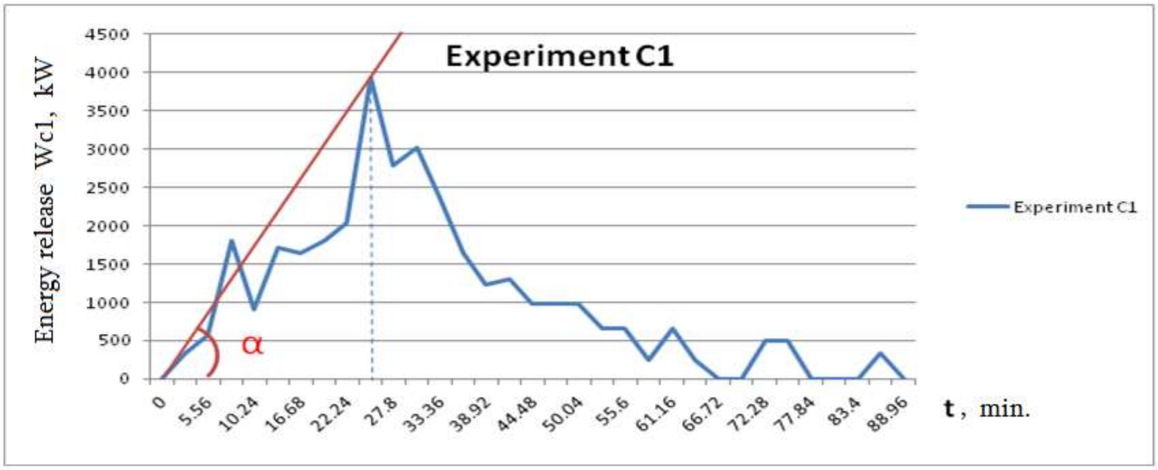

Fig.1. Changing of energy release in time on the complete burning of the passenger car

The results of similar experiments in situ we have analyzed in order to obtain of the average data and their subsequent generalizations. During analysis an average speed of release thermal energy as result of fire were calculated for the rising phase of the fire by the formula

$$\langle V_{AV} \rangle = \frac{\sum_{i=1,n} Wp_i}{\sum_{i=1,n} Tp_i} \ , \qquad (1)$$

where V_{AV} is the average speed of allocated capacity in a rising phase, kW/min; Wp_i - the peak of the heat during of experiment in situ, the subscript i denotes the value of the quantity at point i, kW; Tp_i - the necessary period to achieve peak value of the released energy for the point i, min; n- number of experiments in situ.

The average time to achieve a peak of the thermal energy may be calculated by the formula

$$\langle Tp_w \rangle = \frac{\sum_{i=1,n} Tp_i}{n} \, , \qquad (2)$$

and the average weight loss - by the formula

$$\langle \Delta M_{AV} \rangle = \frac{\sum_{i=1,n} \Delta M_i}{n} \, , \qquad (3)$$

where ΔM_i is the average weight loss during of experiment in situ, the subscript i denotes the value of the quantity at point i, kg.

It should also be noted that the power to fire up to 30 MW the formulas (1) - (3) can be used as in the table 2 corresponding data of relative mass loss, from our point of view, quite agrees well with experiment in situ. Thus, in this case,obtains the following inequality

$$\frac{\Delta M_{W \le 30}}{M_{W \le 30}} \le \frac{\Delta M_{W \exp}}{M_{W \exp}} \, . \qquad (4)$$

Thus, foundation stone is the analysis of the presented materials and we expect that the approximation of the experimental results will be reliable for up to 30 MW fire power, as the burning materials in vehicles are similarly from 5 to 30 MW.

We believe that based on the averaged experimental results and with computer simulation by means of CFD models can be getting spatial and temporal criterion for evaluation. These criterion may be rooted on the quantitative assessment of destructive factors. During fires in the tunnels the damaging factors of health are: abnormal temperature fields, thermal radiation, dust of soot, toxic gases, such as CO, NO_x, HC, SO_x and others. Due to the fact that carbon monoxide gas is decisive in terms of the dilution of toxic concentrations of other gases in products of burning, we believe carbon monoxide is decisive gas for the assessment of toxicity extracted gases during fire. The damaging effect of the abnormal temperature is not in doubt. Therefore, we believe that it is appropriate to take into account only two damaging factors. These factors are: abnormal spatial field distribution of temperature and carbon monoxide concentration within the limits of the underground space.

Numerical data of average time of occurrence hypothermic shock depending on the ambient temperature is shown in Table 3, and Table 4 shows numerical values of the average time of toxic poisoning for human caused by the influence of carbon monoxide [6].

Table 3

The average time of occurrence hyperthermic shock for human

The ambient temperature, ^0C *	80	75	70	65	60	55	50	45	40
The limit of human endurance, min	1	3	5	7	10	30	40	1000	14000

*Fluctuations of relative humidity: 50-100%.

Table 4

The average time of occurrence of toxic poisoning for human

The concentration of CO, mg/m^3	12000	11500-5500	5500-3500	3500-2500	2500-1800	1800-800	800-600
The limit of human endurance, min	1-2	2-5	10-15	20-30	40-80	60-120	120-320

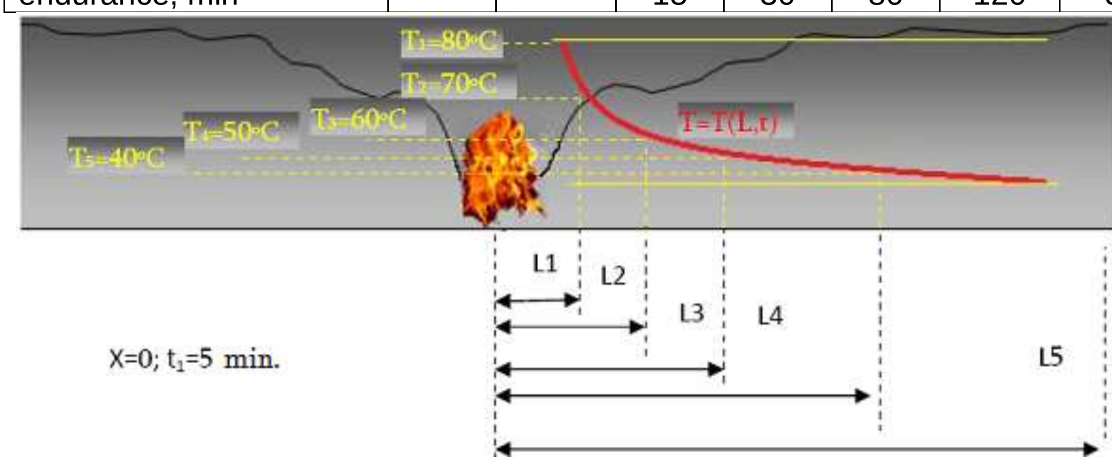

Fig. 2. Spatial dynamics of the temperature field from the start of the fire after 5 minutes

Based on the foregoing, according to the above criterion for a specific tunnel can create a dynamic map of damaging factors - fields of temperature and concentration of carbon monoxide. Marked cards will allow under the initial and boundary conditions of the fire to adequately determine the method and tactics of evacuation. Figures 2 and 3 are given as an example procedure for preparation of the spatial and temporal criterion for the temperature field according to the data of Tables 1 and 3.

The similar distribution of the peak for the $\langle \boldsymbol{Tp}_w \rangle = 25$ minutes will have a look gived below.

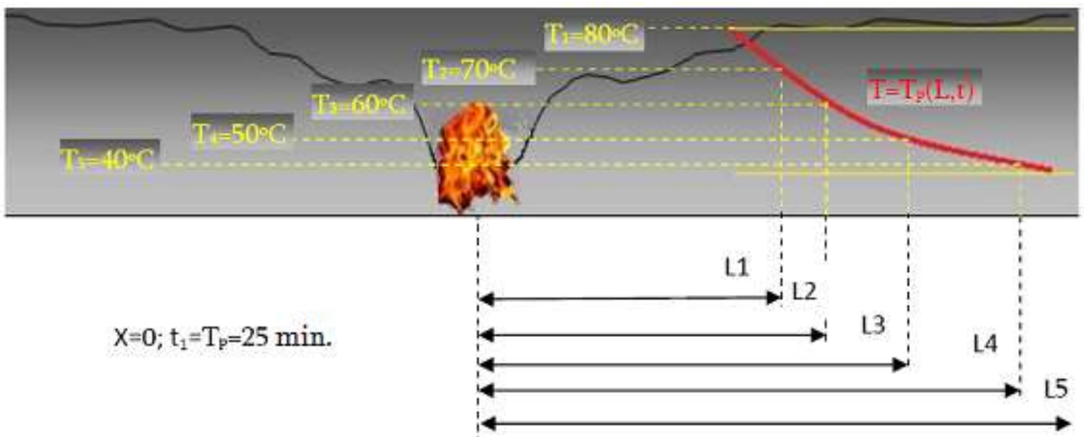

Fig. 3. Spatial dynamics of the temperature field from the start of the fire after 25 minutes

4. CONCLUSIONS

During fires in tunnels, the various degrees of potential danger to human health would be described quantitatively by means of the physical and mathematical modeling of different scenarios of progress of fires in tunnels.

Spatial and temporal criterion of possible damage of people that are proposed for assess of the emergency situations in the tunnels are closely related to the dynamic processes of the spatial and temporal distribution of hazards.

Classification of hazards using the proposed criterion, as well as results of adequate CFD modeling of fires, can be the basis for the assessment and management of emergencies in the tunnels.

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