ON THE CALCULATION OF THE INTENSITY OF THERMAL RADIATION IN A FIRE

Khadija Jahangirova, Elman Iskandarov, Fidan Ismayilova

•

Azerbaijan State Oil and Industry University
xedi1996@mail.ru
e.iskenderov62@mail.ru
fidan.ismayilova.2014@mail.ru

Abstract

The paper analyzes the existing methods of calculating the intensity of thermal radiation at fire, which are presented in normative and methodological documents.

It is established that the existing method of calculation contains errors and does not allow obtaining a reliable result. The method of calculation of the conditional probability of people being affected by fire is not suitable for practical application, as outside the burning spill of flammable liquid the UWPL is always equal to zero, and inside the spill the method has no solution.

Keywords: Fire, probability, thermal radiation, oil spill, premises, personnel.

I. Introduction

As it is known, in order to calculate the intensity of thermal radiation at fire there are several normative documents containing the calculation methodology [1÷5]. Sources [1, 2, 3] contain practically the same calculation methodology. All sources give the same formula, but it has different spelling.

The main disadvantage of the considered methodology is that it does not allow to determine the value of the probit function, and hence the value of the conditional probability of defeat of a person located in the focus of combustion. Outside the combustion center at any scale of release (up to 50000m3 of oil was investigated) the probability of human injury is equal to zero. The question arises, who needed to develop such a complex calculation methodology, if the result is known without its implementation: in the area of the spill we have full uncertainty, and beyond its boundaries - zero result. The zero result outside the spill boundary can be declared without performing the calculation.

Some design organizations take the liberty of claiming that in the burned area the conditional probability of human casualties is 100%. This is not true. This assumption has a practical refutation.

Different representation of equations of one and the same methodology in four existing normative documents leads the designer to the state of complete distrust to normative documents. The designer cannot establish the validity of this or that edition of the calculation methodology, because the authors of normative and methodological documents do not respond to the requests of design institutes, referring to the fact that any normative work in the Russian Federation has been stopped with the release of the Federal Law of December 27, 2002 № 184-F3 "On Technical Regulation". The designer is forced to look for additional sources allowing to solve the problem with a higher degree of confidence.

A different methodology is available in the normative document «VNII GOCHS» "Methodology for assessing the consequences of accidents at fire-explosive facilities" (1994) [4]. The use of this methodology allowed to exclude doubtful points in calculations, and also to get the main transition of conditional probability of human casualty with the change of distance to the place of combustible liquid ignition. Comparing the last calculation methodology with the methodology of GOST and NPB, different estimation of heat flux on the surface of burning spills draws attention. If in GOST and NPB for an oil spill fire the intensity of thermal radiation from the flare surface is 10-25 kW/m^2, and with increasing spill diameter this value decreases and does not exceed 10 kW/m^2, then in the methodology of VNII GOCHS this value has a constant value of 80 kW/m^2.

Figure 1 shows the results of calculating the intensity of thermal radiation (ITR) at a distance of 2 m from the boundary of 10 m^3 of oil according to the methods of NPB [2], VNII GOCHS [4] in comparison with the experimental data of Taubkin S.I. [5].

Comparison of the presented results reveals the following:

1. The NPB methodology gives a variable value of ITR. At small spill area the intensity increases up to 9 kW/m^2, after which it stabilizes at a constant level. The level of thermal radiation at any value of the spill area does not pose a danger to humans, as they have time to leave the danger zone before the start of the impact. The conditional probability of injury to a person outside the burning area at any oil spill area is zero.

2. The GOCHS methodology defines ITR as a constant value at a much higher level than the FSS methodology. This methodology ensures smooth transition of the conditional probability of human injury when increasing the distance to the boundary of the spill from one to zero, which corresponds to the physical model of the phenomenon under study, although the constancy of the intensity of thermal radiation itself does not agree with the results of experiments presented in the work of Taubkin S.I.

3. The results of the experiment of Taubkin S.I. indicate that the intensity of thermal radiation should increase with increasing the area of the oil spill. To ensure this condition, it is necessary to change the dependence of the surface radiation of the combustion torch. With the growth of the oil spill area this indicator should increase. In GOST R 12.3047-98 and PNB 105-03 it decreases with increasing spill diameter.

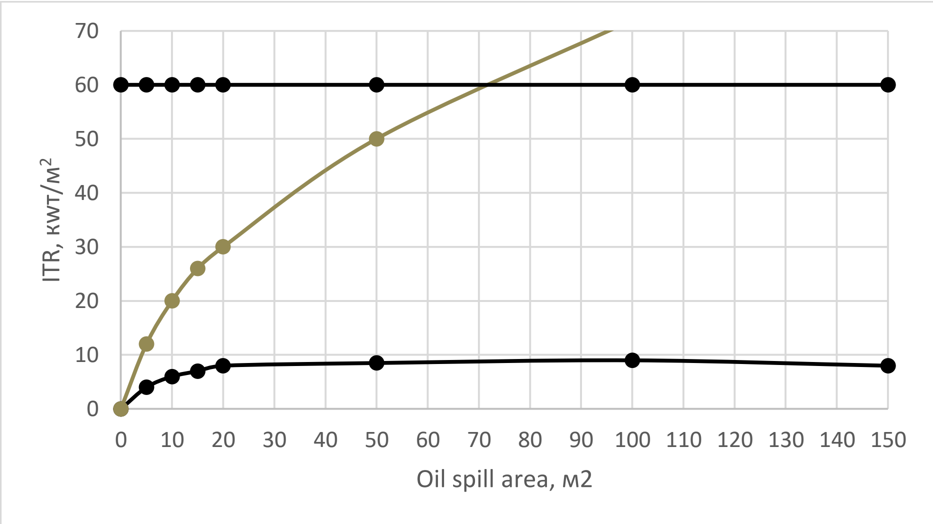

Figure 1: *Comparison of thermal radiation intensity by different methods*

In Fig. 2 shows the dependence of the conditional probability of injury to people from distance to the place of oil release according to the fire safety standards (FSS 105) method. In Fig.3 presents the calculation results in the form of a graph of the dependence of the conditional probability of injury to a person on the distance to the place of the oil release using the authority for civil defense and emergency situations method.

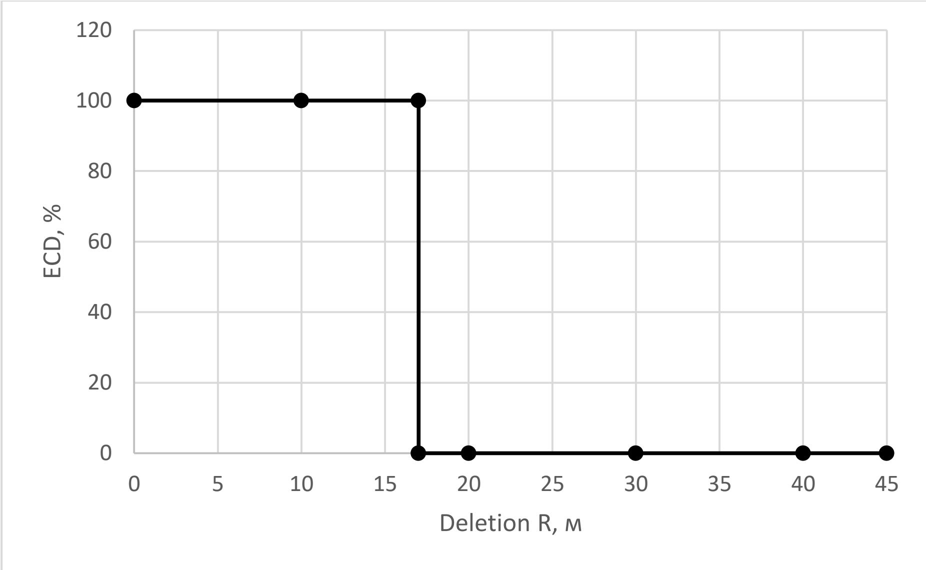

Figure 2: *Dependence of the ECD on the distance to the release site in an oil fire*

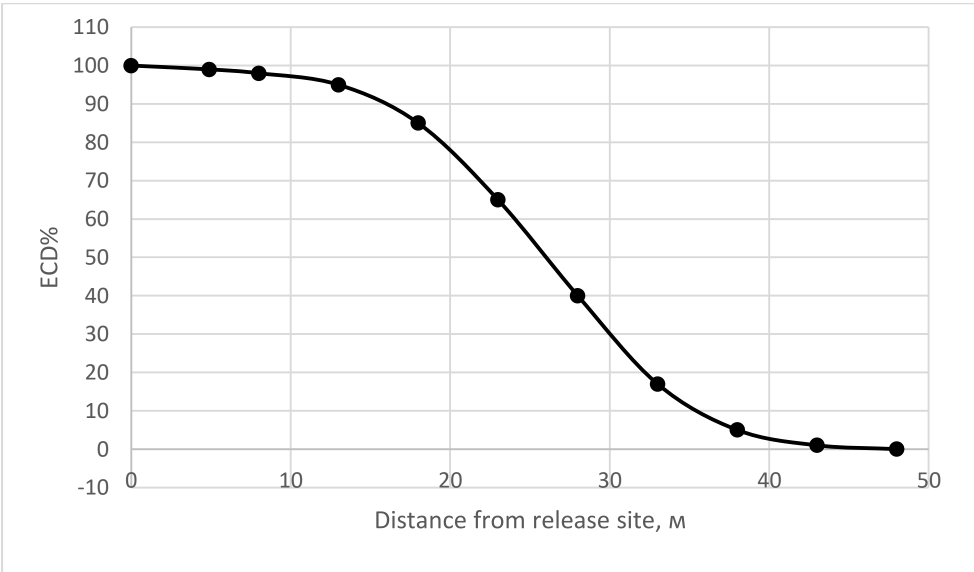

Figure 3: *Conditional probability of people being affected by fire*

A comparison of the considered methods based on the result of calculating the probability of injury to people in a fire revealed, in our opinion, the unsuitability of the fire safety standards method, since it determines the probability of injury depending on the value of the probit function, which is essentially continuous, and the calculation result does not correspond to the continuity condition.

II. Methods

In FSS 105-03 presents methods for calculating the explosion pressure of a hot water supply cloud in an outdoor installation and calculating the conditional probability of injury to a person. Let's consider how these methods are ensured to correspond to each other.

On page 2 of the FSS it is stated that "These standards do not apply to assessing the level of explosion hazard," although all parameters characterizing the fire hazard of outdoor installations are determined by the standards through explosion parameters. In particular, the explosion pressure at an outdoor installation is determined by the equation:

$$\Delta P = P_0(0.8M_{pr}{}^{0.33}Mпр0.33/r + 3M_{pr}{}^{0.66}/r^2 + 5Mpr/r^3) \quad (1)$$

Here Mpr – reduced mass of flammable gas participating in the explosion, expressed in TNT equivalent, кg; r – distance to gas release, m.

Analysis of the presented equation reveals that the pressure tends to infinity as r tends to zero. This pressure dependence during the explosion of a hot water cloud is in conflict with the thermodynamics of the process under consideration. It is known that during the explosion of a hot water supply consisting of air and associated petroleum gas components, the pressure cannot exceed 900 kPa. This feature of the hot water supply explosion is indicated in FSS 105-03 on page 7. For example, find the pressure of the explosive at a distance of 0.5 m, as well as the distance from the explosion site of 1 kg of the reduced mass of methane, at which a pressure of 100 kPa and a pressure of 5 kPa are provided. The explosive pressure at a distance of 0.5 m from the release site is 5408 kPa, which significantly exceeds the maximum value of the explosion pressure.

An explosive pressure of 100 kPa is provided at a distance of 2.65 m, and a pressure of 5 kPa is provided at a distance of 20 m from the place of gas release. Using the equation i=123 Mpr 0.66/r, where i is the pressure wave impulse in Pa min, we determine its value at the found values of r.

İ(100)=1230x10.66/2.65=46.42 Pa min; and İ(5)=123x10.66/20=6.15 Pa min.

Based on the values of ΔP and i, determine the value of the probit function-Pr;

Pr=5-0.26Ln(V), where V=(17500/ΔP)8.4 + (290/i)9.3.

Here ΔP – is the excess explosion pressure in Pa.

After substituting the values into the presented equations, we obtain for ΔP equal to 100 kPa and ΔP equal to 5 kPa the values of Rg, respectively, 0.55 and minus 4.25, which corresponds to the conditional probability of human injury equal to zero.

What is the danger of the investigated air pressure levels? The NPB does not contain data on the assessment of the consequences of the explosion. In GOST R 12.3.047-98 [1] we find that an overpressure of 100 kPa leads to the complete destruction of building structures. In case of complete destruction of building structures, people in the building will probably die. Why is there no data about it in the normative document? It should be assumed that the conditional probability of human injury at such a pressure is estimated at 100%. The result of the calculation according to the methodology of the National Fire Safety Regulations gives a different result - 0%

III. Results

1. The existing method of calculating the intensity of thermal radiation in a fire, presented in normative and methodological documents because of the error does not allow to obtain a reliable result.
2. Methods for calculating the conditional probability of people being affected by fire are not suitable for practical application.

References

[1] GOST R 12.3.047-98 "Fire safety of technological processes" General requirements. Control methods.

[2] FSS 105-03 Fire safety standards. Determination of categories of premises, buildings and outdoor installations on explosion and fire hazard. Moscow, 2003, 48 p.

[3] SP 12. 13130.2009. Determination of categories of premises, buildings and outdoor installations on explosion and fire hazard. M., 2009.

[4]. Methodology for assessing the consequences of accidents at fire and explosion hazardous facilities. «VNII GOCHS», 1994.

[5] Taubkin S.N. Fire and explosion, peculiarities of their expertise. Moscow, 1999, 600 p.