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QUANTITATIVE ASSESSMENT OF TECHNOLOGICAL UNIT EXPLOSION HAZARD IN PETROCHEMICAL PRODUCTION

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In this article the general principles of technological units fire and explosion hazards quantitative analysis of chemical, petrochemical and oil refining industries are described. They are also overspread to the newly projected, under construction, reconstructed and functional plants, enterprises and facilities of chemical, petrochemical, oil refining industries.

Keywords: *the energy potential of explosion, the category of explosion, the energy of gas-vapor phase flaring*

According to the requirements of safety regulations of technological process 09- 540-03, automatic and remote control, automatic protection arrangements must maintain the given accuracy of technological parameters, reliability and safety of technological processes [1].

The minimal level of explosion hazard of the technological system units should be ensured while developing the requirements. Therefore, the energy level of every technological unit is estimated and the category of its explosion is determined by calculation; there is also the justification of efficiency and reliability of measures and protection equipment, their explosive safety insurance ability of the given unit and the whole technological system.

It is important to define energy data values of the technological unit explosion for quantitative assessment.

1. The energy explosion potential E (the total energy of gas-vapor phase flaring, which entered the environment during the unit emergency depressurization, kJ) is defined as the total energy of gas-vapor phase flaring in the unit taking into account the

work of adiabatic expansion rate as well as the energy value of total flaring of evaporated liquid from the spill maximum possible area, in this circumstances it is considered that [2 - 4]:

I. in case of the emergency equipment depressurization its total breakage occurs;

II. the liquid spill area is determined on the basis of structural architectural solutions or outdoor site;

III. the time of evaporation cannot be more than 1 hour:

$$E = E_1^{'} + E_2^{'} + E_1^{''} + E_2^{''} + E_3^{''} + E_4^{''}, \qquad (1)$$

where $E_1^{'}$ – the total of adiabatic expansion energies A (kJ) and gas-vapor phase flaring in the unit, kJ;

$E_2^{'}$ – the energy of gas-vapor phase flaring, entered the unpressurized section from associated facilities (units), kJ;

$E_1^{''}$ – the energy of gas-vapor phase flaring, produced by the energy of the overheated liquid phase of the considered unit entered from associated facilities during the time, kJ;

$E_2^{''}$ – the energy of gas-vapor phase flaring, produced from liquid phase by heat generating reactions continuing in case of depressurization, kJ;

$E_3^{''}$ – the energy of gas-vapor phase flaring, produced by heat gain from external heat transfer media, kJ;

$E_4^{''}$ – the energy of gas-vapor phase flaring, produced from spilled liquid phase on the solid surface (a floor, a pallet, soil and etc.) by environment heat emission (from solid surface and air to liquid over its surface), kJ.

2. $E_1^{'}$ – the total of adiabatic expansion energies A (kJ) and gas-vapor phase flaring that is in the unit (kJ) is given by:

$$E_1^{'} = G_1^{'} q^{'} + A, \qquad (2)$$

where $G_1^{'}$ – the mass of gas-vapor phase, which is present in the unit or entered during the emergency unit depressurization from the associated units;

$q^{'}$ – specific heat of gas-vapor phase flaring;

A – the energy of compressed gas-vapor phase flaring, contained in the unit itself and entering from the associated units, is considered as work of adiabatic expansion during the emergency unit depressurization.

To determine the energy of gas-vapor phase flaring adiabatic expansion the following equation can be used:

$$A = \beta_1 P V^{'} , \tag{3}$$

where P – specified absolute pressure in the system and in the unit;

$V^{'}$ – geometric volume of gas and vapor in the system or in the unit;

β_1 – the dimensionless ratio taking into account both the pressure P and specific heat ratio k of gas vapor phase flaring. It can be accepted according to the Table 1.

Table 1

The value of ratio β_1 according to specific heat ratio and pressure in the technological unit

specific heat ratio	Pressure in the system, MPa									
	0,07-0,5	0,5-1,0	1,0-5,0	5,0-10,0	10,0-20,0	20,0-30,0	30,0-40,0	40,0-50,0	50,0-75,0	75,0-100,0
k = 1,1	1,60	1,95	2,95	3,38	3,08	4,02	4,16	4,28	4,46	4,63
k = 1,2	1,40	1,53	2,13	2,68	2,94	3,07	3,16	3,23	3,36	3,42
k = 1,3	1,21	1,42	1,97	2,18	2,36	2,44	2,50	2,54	2,62	2,65
k = 1,4	1,08	1,24	1,68	1,83	1,95	2,00	2,05	2,08	2,12	2,15

When the values are excessive $P < 0{,}07$ MPa and $PV^{'} < 0{,}02$ MPa the adiabatic expansion energy of gas-vapor phase (A) may not be taken into account due to its small values.

The mass and volume values for multicomponent medium are defined in respect of percentage and physical properties of products composing this compound or determined by one component that accounts for a sizerable proportion of it.

3. $E_2^{'}$ – the energy of gas-vapor phase flaring, entered the unpressurized section from associated facilities (units), kJ [5-6]:

$$E_2^{'} = \sum_{i=1}^{n} G_i^{'} q_i^{'} , \tag{4}$$

where $G_i^{'}$ – the energy of gas-vapor phase flaring, entered the unpressurized section from associated units during the emergency unit depressurization;

$q_i^{'}$ – the specific heat of gas-vapor phase flaring.

4. $E_1^{''}$ – the energy of gas-vapor phase flaring, produced by the overheated liquid phase energy of the unit under consideration entered from associated facilities per unit time, kJ:

$$E_1^{''} = G_1^{''}\left[1-\exp\left(-c_1^{''}\theta_K / r\right)\right]q^{'} + \sum_{i=1}^{n} G_1^{''}\left[1-\exp\left(-c_1^{''}\theta_{K_i} / r_i\right)\right]q_i^{''}, \qquad (5)$$

where $G_1^{''}$ – the mass of liquid phase, that is present in the unit or entered it during the emergency unit depressurization from the associated units;

$c_1^{''}$ – the specific heat of the liquid phase;

θ_K – the temperature difference of the liquid phase in specified state and its boiling under atmospheric pressure;

r – the specific heat of flammable liquid evaporation;

$q^{'}$ – the specific heat of gas-vapor phase flaring.

5. $E_2^{''}$ – the energy of gas-vapor phase flaring, produced from liquid phase by heat generating reactions continuing in case of depressurization, kJ:

$$E_2^{''} = \frac{q^{'}}{r}\sum_{i=1}^{n} \prod_{P_i} \tau_{P_i}, \qquad (6)$$

where Π_{P_i} – the heat flux rate to the gas-vapor phase due to the total heating effect of heat generating reactions;

τ_{P_i} – is accepted for each case on the basis of concrete specified process realization conditions and the reaction time of cutoff devices and emergency shutdown system.

6. $E_3^{''}$ – the energy of gas-vapor phase flaring, produced from liquid phase by heat flux from external heat transfer media, kJ:

$$E_3^{''} = \frac{q^{'}}{r}\sum_{i=1}^{n} \prod_{T_i} \tau_{T_i}, \qquad (7)$$

где Π_{T_i} – the heat flux rate to the liquid phase from external heat-transfer media;

τ_{T_i} – the time from the emergency unit depressurization till the total stop of coolant delivery to the emergency unit (the heat exchange process stop);

7. $E_4^{''}$ – the energy of gas-vapor phase flaring, produced from spilled liquid phase on solid surface (a floor, a pallet, soil and etc.) by environment heat emission (from solid surface and air to liquid over its surface), kJ:

$$E_4^{''} = G_{\Sigma}^{''} q^{'}, \qquad (8)$$

where G''_Σ – the total mass of the liquid phase, evaporated due to the heat gain from the environment;

q' – the specific heat of gas-vapor phase flaring;

The approximate value of G''_Σ can be defined due to the Table 2.

Table 2

The mass of gas-vapor phase spill depending on its boiling point at τ =180 c

The value of liquid phase boiling point t_k, ºC	The mass of gas-vapor phase G_Σ, kg (at F_n = 50 m^2)
above 60 < 10	<10
from 60 till 40	10-40
from 40 till 25	40-85
from 25 till 10	85-135
from 10 till -5	135-185
from -5 till -20	185-235
from -20 till -35	235-285
from -35 till -55	285-350
from -55 till -80	350-425
below -80	> 425

The values of the given mass and the relative energy potential characterizing the technological unit explosion risk are defined according to the values of total energy explosion potentials E.

The total mass of inflammable vapor (gas) of dangerously explosive gas-vapor cloud *m*, reduced to the common specific flaring energy, equal to 46 000 kJ/kg:

$$m = \frac{E}{4{,}6 \cdot 10^4}, \tag{9}$$

where E – the total energy, released at flaring of unevaporated mass of liquid phase during the unit depressurization emergency.

The relative explosion risk energy potential of the technological unit is calculated by:

$$Q_B = \frac{1}{16{,}534}\sqrt[3]{E}. \tag{10}$$

The technological units are divided into categories according to the values of relative energy potentials Q_B and the given mass of gas-vapor medium *m.*

The category values are given in the Table 3.

Table 3

The values of technological unit explosion categories

The category of explosion	Q_B	*m,* kg
I	> 37	> 5000
II	27-37	2000-5000
III	< 27	< 2000

The calculation procedures and procedures of explosion levels assessment of the standard technological train units or separate processes must be developed taking into account the foregoing principles. The worked out procedures are to be authorized in accordance with the established procedure in the territorial bodies of Russian Federal Service for Ecological, Technological and Atomic Supervision.

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