Fire Science & Technology Vol. 16 No. 1 & No. 2 (35~40) 1996

A PROSPECT OF DEVELOPMENT SUB SURFACE INJECTION METHOD EXTINGUISHING OF FIRES OF PETROLEUM

A.F. Sharovarnikov, A.A.Efimov

ABSTRUCT

Necessity of development of domestic variant Sub Surface Injection method extinguishing of fires of petroleum in tanks is shown. Main stages of process extinguishing of fires in the tanks Sub Surface Injection method by a way are analyzed. Results of Laboratory and natural tests Sub Surface Injection method extinguishing with application domestic foam bilding analysis.

Situation, combined are indicated at extinguishing of fires in tanks by regular means and ways, shows necessity of development of new system extinguishing, having real efficiency and smaller risk for staff, engaged in extinguishing of a fire.

In foreign practice the alternate decision on the maintenance extin-guishing is the application Sub Surface Injection method extinguishing.

For the realization Sub Surface Injection method extinguishing usual foam bilding are not suitable, as far as they are well mixed with a petro-leum, and foams are completely destroyed in a thicker fuel. In result, on a surface of a liquid mount only bubble of air.

The firm "3M" (USA) was developed in essence by new type foambilding, received name " Light water ", the solutions of which differed unusually by a low surface tension. This fact has allowed to execute ear-lier impossible phenomenon, namely - spontaneous movement of drops of a water solution on a surface of petroleum. As a result, the surface of a fuel appears by a covered continuous thin film of a water solution, which sharply reduces speed of evaporation of a petroleum. As a result, the surface of a fuel appears by a covered continuous thin film of a water solution, which sharply reduces speed of evaporation of a petroleum.

Received from a type " Light water " foams, should not be mixed with a petroleum. At submission in a layer of petroleum foams mounts on a surface and forms a continuous dense layer, which terminates access of a fuel of a gas in a zone of burning.

Experimental researches and the natural tests have confirmed high efficiency of structures of a type "Light water " at realization Sub Surtace Injection-method extinguishing of fires. In a number of countries fire-prevention of tanks with a petroleum provide with systems Sub Surface Injection method extinguishing of fires from a mobile engineering, instead of a automatic system extinguished [1].

The work on development of domestic variant fires were constrained on a number of the objective reasons and, first of all, because of absence in country of manufacture of foambilding thosetype "Light Water ". After development in 1986 small-scale manufacture foambilding "Foretol", using fluor Substance of connection and intended for extinguashment of fires ethanol and methanol, systematic researches on development of domestic variant "Podsloyny" of a way extinguashment of fires of petroleu fires about spirits, systematic researches on development of domestic variant Sub Surface Injection method extinguishing of fires of petroleum in tanks [2–5], are begun.

With the beginning of manufacture of new marks foam bilding, such as "Universalny " and "Podsloyny" [6], the prospect of introduction Sub Surface Injection method extinguishing in the nearest years becomes real. Thus, alongside With the decision of a number of technical problems of development of a new Way is coming to overcome a barrier of traditions on away of his introduction to practice and recognition's in the normative documentation.

Despite twenty years of application Sub Surface Injection method extinguishing of fires abroad in a opened Seal its analysis and theoretical substantiation is away, nor express trains - methods of definition of efficiency foam bildings, suitable for its realizationare published.

Domestic foambilding strongly differ from foreign analogues on a nature of initial raw material, that does not permit directly to use the known recommendations for realization of a new way. The development

domestic Sub Surface Injection method extinguishing of fires requires the decision of a number of main questions, including:

- development of scientific principles, enabling to execute Sub Surface Injection method extinguishing of fires;
- creation special foambilding, which prevents the mixture foam with a petroleum, during its rise through a layer of a fuel;
- development of a generator of high back pressure, for the reception low expansion foams;
- revealing of optimum modes for the input foam in a tank.

The theoretical researches were directed on revealing of role foam-bildings in maintenance spontaneous formation of a Water film and maintenance of thermal stabilization foam, prevention of pollution with a petroleum.

The development special foambilding is conducted on base of domestic raw material. Comparison to foreign analogues, modified variants "Universalny" foam bilding and again created foam bilding "Podsloyny", answer a level known foam bilding "Light Water". So, the optimum intensity of submission foam from these structures does not exceed size of $0.08 kgs/m^2/s$.

The process extinguashment of fires of combustible liquids by submission foam fromunder a layer of a fuel can be divided into some stages:

- reception and transportation foam inside of a tank;
- Spontaneous rise and contact destruction foam by a layer of a fuel;
- updating and cooling of a surface layer of a fuel by a flow foam merge foam bubble and formation foam of a layer on a surrace of a liquid;
- the movement foam on a surface petroleum ;
- the thermal destruction foam under action of a flame.

Depending on size of a surface tension on the border foam - the petroleum will vary volume foam bubble, on which will be divided foam at a input in a liquid. As a result of the rise foams a certain structure of speeds of a liquid as inside a tank, as on its surface is established. At this stage long and comprehensive contact to a petroleum and occurs only the special properties on a surface-active substance prevent absorption of fuel foams.

The stage of the merge foam bubble in uniform foam a layer is a important moment, from which ability foam depends exstinguishing. Process of connection foam bubble the layer of a petroleum is constantly superseded from a zone of contact foam. If application rate of submission foam not large, and the wetting foam with a hydrocarbons is excluded, the layer foam will be without pollution. At the high application rate foam the fuel will appear seized foam.

The optimum modes of submission foam and concentration foambilding in water solutions were fulfilled on installation, submitted on fig.1 .

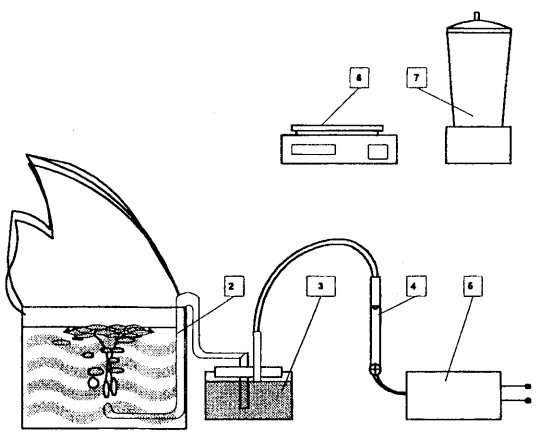

Figure 1: The circuit of installation for definition extinguishe of efficiency by submission foam in a layer of a combustible liquid:

1,2 - Tank with combustible liquid;
3 - Capacity with foam; 5 - Compressor;
6 - Device for weighing; 7 - Foam maker.

Tested foams of small volume from 4.0 up to 6.5. As combustible liquids used individual hydrocatbons, sach as liquids. As well as petrol of the various marks.

Natural tests conducted in three stages, including detailed research the extinguashment of tank in volume $30m^3$ (height $4m$ and area $10m^2$), further-on a tank by capacity $700m^3$ (height $8m$ and area $70m^2$) and in summary - on a tank by capacity $2000m^3$ (height $12m$ and area $150m^2$). As a combustible liquid used light and standart petrol, oil and other.

The circuit of system Sub Surface Injection method extinguishing of a tank (mobile), is shown on a drawing of fig.2.

The results of tests, which were received at extinguishing of a tank in volume $30m^3$ and $700m^3$, are shown on fig.3.

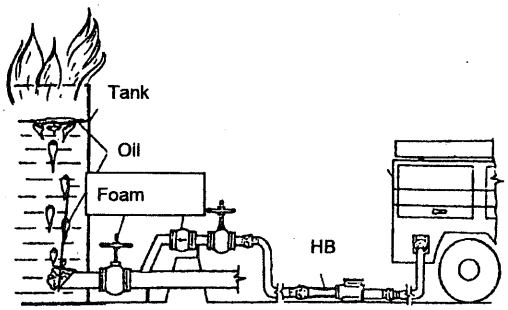

Figure 2: The circuit of system Sub Surfese Injection method extinguashing of a tank(mobile):

1 - Radical the valves(gate) of a tank;
2 - return valves;
3 - High back pressure generators; Tank with foam making liquid concentrate.

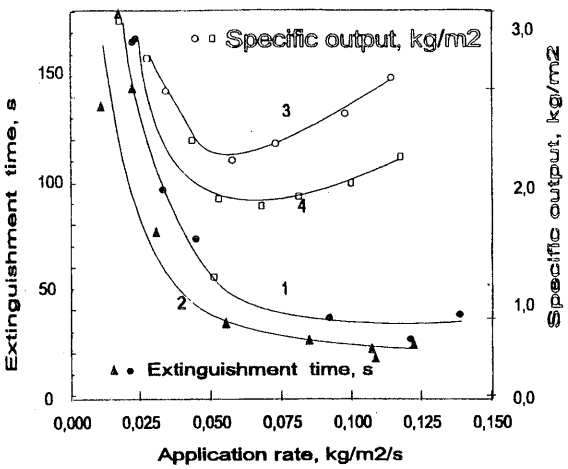

Figure 3: Extinguishment of a petrol(1,3) and light fuel (heptan) 2,4, with foam on the basis foambuilding – "Universalny":

1,2 - dependence of time extinguishing on intensity of submission fosm;
3,4 - dependence of the specific charge on intensity of submission fosm.

For a conclusion of settlement parities, describing process extinguishing of petroleum foam, we shall record a equation of the material balance:

$$q d\tau = \rho_f h S_0 d\theta + u_T S_0 \theta d\tau \qquad (1)$$

where

q_f - charge foam, kg/c;
ρ_f - dencity foam, kg/m^3;
h - average height of layer foam, m;
S_0 - area of a surface of burning;
Q - degree of cover of a surface;
S_f - area of a surface under foam, m^2;
U - specific speed of thermal destruction foam, $kg/m^2/c.$, $\theta = S_f/S_0$

For the decision of a equation of the material balance it is necessary to reveal dependence of specific speed of thermal destruction foam on a degree of cover by her burning of a surface. A flow is warm from a flame up to very small significances, In accordance with cover of surface foam changes from maximum size, to appropriate to conditions of stationary burning of a liquid.

Foambildings "Foretol" and "Universalny" (Fluorsintetic) at heating of their water solution to temperature of boiling at all do not lose surface activity, therefore we shall accept, that foam is destroyed as a result of evaporation of a outside layer foams film. Then, the expression for specific speed of thermal destruction of the foams will accept a kind :

$$u_t = \frac{q_T}{zQ_b} \qquad (2)$$

where

q_T - flow is warn;
Q_b - specific heat, necessary for heating of water solution and evaporation of water,
z - a factor of the form foam bubble.

As far as for destruction of layer foam it is enough to heat only out-side layer foam bubble, quantity required for this purpose is warm less, than it is necessary for heating of all weight of a water in the outside layer foam. Therefore into the formula (2) factor of the form is entered in the denominator, the significance's of which change from 0.5 up to 0.3.

We shall express a flow is warm from a flame per unit of a surface through the specific speed Burning and area of a surface of burning:

$$q_T = u_m^0 Q_S (1 - \theta) \qquad (3)$$

where

u_m^0 - The specific speed burning of a liquid in a stationary mode;

Q_S - specific heat Heating and evaporation's;

θ - Degree of foam cover of a surface.

Having substituted expression (3) in the formula (2), we shall receive quantitative interrelation of specific speed of thermal destruction foam from a degree of cover of a surface of burning:

$$U_T = U_0(1-\theta) \tag{4}$$

where

$$U_0 = U_m^0(Q_S/zQ_W) \tag{4a}$$

In view of expression (4) we shall transform a equation of the Material balance (1), previously having divided of both parts of a equation on the initial area of a surface of liquid So, having designated the attitude

$$\begin{aligned} q/S_0 &= \Im \\ \Im d\tau &= \rho_f h d\theta + u_T(1-\theta)\theta d\tau \end{aligned} \tag{5}$$

After division variable and reduction of a differential equation to a kind, convenient for integration, we shall receive:

$$d\tau = \frac{h\rho_f d\theta}{\theta^2 u_0 + (-u_0)\theta + \Im} \tag{6}$$

Having taken integral ofequation (6) in limits from $\tau = 0$, $\theta = 0$ up to $\tau = \tau_T$, $\theta = 1$, we shall receive expression

$$\tau T = \frac{4h\rho_f}{\sqrt{(4\Im - u_0)u_0}} arctg \frac{u_0}{\sqrt{(4\Im - u_0)u_0}} \tag{7}$$

The critical situation of clearing, when the time t r r will be realizedin case, when the size under radical of expression in a denominator of fraction will become to a equal zero, i.e. At $(4I - u_0) = 0$, $tT = G$. We shall receive expression for of the critical intensity of submission foam (with the account (record-keeping) (4a))

$$\Im_{kp} = \frac{u_0}{4} = \frac{u_0 m Q_{\tilde{a}}}{4zQ_b} \tag{8}$$

We for convenience of the analysis of model of the clearing shall presentexpressions of trigonometric functions by the first members appropriatestepeny of numbers. Thus the error of definition of a time of the clearing willnot exceed of of 15 %

$$\tau_t = \frac{\rho_f}{\Im - \Im_{kp}} \tag{9}$$

The expression (9) permits to conduct the graphic analysis of results of experimental researches, received in range intensity, commensurable with $\Im_{kp}$. If to present results in coordinates $1/r = f(\Im)$, the linear dependence can define size of critical application rate pursuant to the formula :

$$\frac{1}{\tau} = \frac{\Im}{\rho_f h} - \frac{\Im_{kp}}{\rho_f h} \tag{10}$$

We shall present average thickness foams of a layer in a kind of a half-sum of thickness in a place of fall foam hq and minimum extinguishing (isolator) The layer h_0, and $h_q = \beta\Im$ and h_0 - the size constant, is defined by a nature of a foamer. Parameter β is defined by the attitude $h_0/\Im_{kp}$, i.e.

$$\beta = \frac{h_0}{\Im_{kp}} \tag{11}$$

Then

$$h = \frac{1}{2}(h_0 + h_q) = \frac{1}{2}(h_0 + \beta\Im) \tag{12}$$

We shall substitute expression (12), with the account (record-keeping) (11), in the formula (9)

$$\tau T = \frac{\rho_f h_0}{2\Im_{kp}} \frac{\Im_{kp} + \Im}{\Im - \Im_{kp}} \tag{13}$$

The formula (13) describes dependence of a time of the clearing from intensityof submission foam at any significance $\Im \geq \Im_{kp}$.

At $\Im \to \infty$

$$\tau T \to \frac{\rho_f h_0}{2\Im_{kp}} \equiv \tau_0 \tag{14}$$

τ_0 - minimum time of the clearing of a flame.

We shall reveal optimum parameters of process of clearing, the observance of which permits to extinguish a fire with minimum costs of the foamer of a solution. We shall record expression for specific costs of the foamer on clearing of unit of the area of burning

$$G = \Im \cdot \tau = \frac{\tau_0 \Im(\Im_{kp} + \Im)}{\Im - \Im_{kp}} \tag{15}$$

Where

$$\tau_0 = \rho_f h_0 / 2\Im_{kp}$$

The dependence G from J has a minimum at $\Im = \Im_{opt}$, therefore for definition of optimum intensity of submission of the foams derivative $(dG/d\Im)$ we equate to a zero

$$\frac{dG}{d\Im} = \tau_0 \left\{ \frac{\Im(\Im_{kp} + \Im)}{\Im - \Im_{kp}} \right\}^* = 0 \tag{16}$$

We after differentiation and shall receive decisions of a square equation

$$\Im_{opt} = 2.4\Im_{kp} \quad (17)$$

Having substituted the significance $\Im_{opt}$ in expression (15), we shall find minimum specific costs of the foamer on clearing of a fire.

$$G_{\min} = 2.9\rho_f h_0 \quad (18)$$

The formulas (17) and (18) are approximate, as far as are received on the basis of a simplified parity (9), instead of the exact decision of the formula (7).

On fig.4 results natural of tests of the clearing of a petrol by the foamer "Universalny " are shown. There by the line results of account under the formulas (13) and (15) are submitted. The satisfactory concurrence these cuNe proves chosen model and the opportunity of a number of simplifications at a conclusion of settlement parities. Dependence of a time of clearing (1) and specific charge foam (2) from intensity of sub-mission foam at the clearing of a petrol

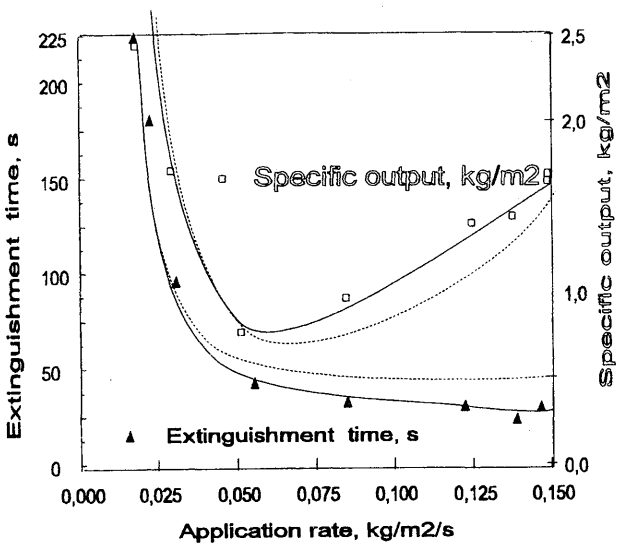

Figure 4: Dependence of a extinguishment time (1) and specific charge foam (2) from intensity of submission foam at extinguished a petrol of the mark A-76 foambilding "Universalny". Week line - account under the formulas (13) and (15).

of the mark A-76 of 6 foamers "Universalny " line - account under the formulas (13) and (15).

The typical dependence of a time of the clearing of a flame petrolium from size of set intensity of submission foam is shown on fig.3 and fig.5, where influence of concentration of the foamer "Universalny" and role of a nature of a combustible liquid is illustrated. By use of the foamer "Universalny " optimum is the concentration about of 6% about. The size of critical intensity of submission foam grows at transition to oil with smaller temperature of boiling.

On the basis not natural of tests was established, that the optimum contents of the foamer "Podsloyny" also makes of 6% about.

The conducted tests of domestic variant "Podsloyny" of a way of submission foam have shown high efficiency of a new system of fire-fighting.

By results of researches and natural of tests the proposals for entering of system "Podsloyny"of the fire-fighting in new edition the law are developed.

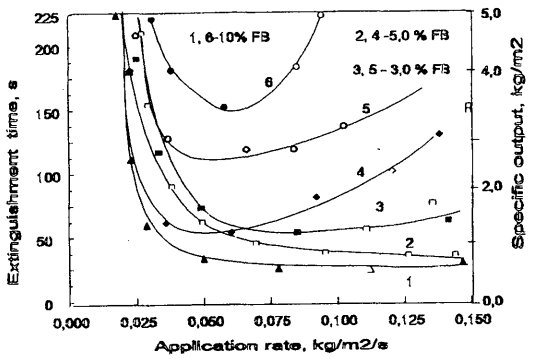

Figure 5: Dependence of a extinguishment time (1-3) and specific charge foam (4-6) from intensity of submission foam the basis foambilding - "Universalny":

1,6 - 10% solution foambilding; 2,4 - 5% solution foambilding; 3,5 - 3% solution foambilding.

LIST OF USED SOURCES

1. Nakakuky A. Historical study of questions of the extinction of fires in petroleum tanks, equipped by system of submission under layer / Hikan Gidzucu nq kenkisy. -1981. -y-No21. -No2. - P.73-77.

2. Sharovarnikov A.F., Aksenov V.P., Grashichev N.K. Laws of the extinction of combustible liquids // A fire engineering, tactics and automatic installations of fire-fighting: Kol. Sins. Work. -M.: VIPTSH, 1989. -P.80-87.

3. Sharovarnikov A.F., Grashichev N.K., Voevoda S.S.. The extinction of fires of inflamable liquids // Methodological problems Maintenance of fire safety: Kol. Sins. Work. -M.: VNIIPO, 1991. -P.94-100
4. Sharovarnikov A.F.,Teplov S.G. The analysis of main paritiesin the theory of the extinction of fires foams // A fire engineering and The extinction of fires: Kol. Sins Work. -M.: VNIIPO, 1990. -P.111-119.
5. Grishin V.V.. A condition of a problem of fire-prevention protection of tanks // Theoretical and experimental questions automatic of fire-fighting: Kol. Sins. Work. -M.: VNIIPO, 1987. -P.24-32.
6. Sharovarnikov A.F., Teplov S.G. Tests new foam-bilding // Fire business. -1990. -No12. -P.34.