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THE FILLING-OUT OF COMBUSTIBLE FLUIDS ONBOARD SPECIFIED SHIPS

Gheorghe SAMOILESCU, Alina BARBU,
Mircea CONSTANTINESCU, Vergil GRADINARU

"Mircea cel Batran" NAVAL ACADEMY – Constanta, ROMANIA

ABSTRACT:

Loading filling out and unloading operations of oil products can result in electric storage that can be turned into electric discharges.

This paper focuses on the conditions to be taken into account for the crew, ship and environment safety, in the case of combustible fluids onboard specialized ships considering the plusical and chemical phenomena that acher. Specific measures against electric discharges can be taken if the occurrence and evolution of electric load in the lines and compartments of the ship are known. An analysis is made on the methods of electric loading of oil products, the role of the water in the oil emulsion, the role of inversion, the need for the implementation of normsand recommendations within the Romanian Ship Register. Based on the charts showing combustible fluids loading during the transportation, through lines according to electrical resistivity, tables are drawn for the differences in limit potential for cargo and ship safety. The analysis of production and storage mechanisms of electric loads within lines as well as the determination of load sensity evolution allow for an analysis of safety conditions of navigation on the seas, oceans and in the harbors of the world.

KEYWORDS: *electrostatic load; combustible liquid; flowing current; diffusion; migration; connection of electric load*

1. INTRODUCTION

When flowing through pipes, combustible liquids get charged with electricity. When electric load appear their value is determined by a process of setting up a double electric layer, which represents a spatial distribution of electric of electric loads on the contact surface of the liquid phase with the wall of the specific pipe.

The equations which govern the distribution of electric loads in the case of flowing combustible liquids of low conductivity enable us to make a compression between experimental results and theoretical results, in order to ensure a better understanding of the phenomenon of electrostatic charging.

Static electricity present a risk of fire and explosion during loading, unloading, decantation and storage of oil products is due to the impurities which are deposited.

Where the oil liquid comes in contact with the wall of the delivery pipe, Wan der Waals and Coulomb resulting forces can be channeled towards the interior or the exterior of the pipe depending on the sign of the load on the product to be carried.

The production of electric loads when liquids move about can be explained on the grounds of a specific feature of the separation boundary between the liquid and the solid phase [1]. The maximum depth at which the loading particles may penetrate from one surface to the other in order to obtain a measurable separation of loads is $5\cdot10^{-10}$ m for the electrons and $25\cdot10^{-10}$ m for the ions [2] [3].

Any displacement of the liquid trigger a shipping of fixed loads as opposed to free ones within the double electric stratum, creating thereby an electric current and the possibility to accumulate electric at both ends of the tract. Therefore, the combustible liquid which flow through pipes gather the loads non-absorbed by the walls of the pipes and conveys them as a spatial load in the storage area.

The appearance of electrostatic discharge depends on the composition of the combustible substances, the percentage of generation and relaxation of the electric load, the gradients, the outcoming potential, the volatility and inflammability of component substances within the oil product, the minimum ignition energy of mixtures.

Both the electric charging and the electric conductivity of a combustible product are due to the presence of ions. The accumulation of electric loads is dangerous because it is achieved by means of an increase in the intensity of the electric field. In the case of oil liquids which have an electric risistivity greater than $10^7 \div 10^8 \Omega\cdot m$ when passing trough pipes, the electric lead increases conversely proportional through the section of the pipe and directly proportional to the flowing speed, the rugosity of the interior surface of the pipes and its length.

2. GENERAL EQUATIONS WHEN CARRYING LIQUIDS THROUGH PIPES

In conformity with the researches which have been made in hydrodynamics, due to the ions of opposite signs, which take part in the laminar movement as well as in a turbulent movement, the thickness of the double electric stratum is [4]

$$\delta = \sqrt{\frac{RT\cdot\varepsilon_0\cdot\varepsilon_r}{2C\cdot F^2\cdot z^2}} \tag{1}$$

where: R- universal constant of gases
F-Faraday number
C-concentration of ions
Z-ion valence
T-absolute temperature
$\varepsilon = \varepsilon_0\cdot\varepsilon_r$ - electric permitivity

In conformity with Stern's models, the double stratum is made up of two different liquid strats: the compact stratum, close to the wall and the diffuse stratum, who's thickness is proportional to the square root of liquid resistivity.

The equation which govern the diffuse stratum are:

a) conservation equation

$$div\,\bar{j} + \frac{\partial\rho^*}{\partial t} - \beta\frac{\partial\sigma^*}{\partial t} = 0$$

$$div\,\bar{j} + \frac{\partial\sigma^*}{\partial t} - \frac{\partial\rho^*}{\partial t} = 0 \tag{2}$$

b) Poirson's equation

$$\Delta\Psi = -\frac{1}{\varepsilon}\left(\rho^* - \beta\sigma^*\right) \qquad (3)$$

c) equation of electric current density

$$\vec{j} = -D_0 grad\vec{d}\rho + \frac{e_0 z D_0}{KT}\cdot\sigma^*\cdot grad\vec{d}\Psi + \left(\rho^* - \beta\sigma^*\right)\vec{v}$$

$$\vec{j}^{\,*} = -D_0 grad\vec{d}\sigma^* - \frac{e_0 z D_0}{KT}\cdot\rho^* grad\vec{d}\Psi + \left(\sigma^* - \beta\rho^*\right)\vec{v} \qquad (4)$$

with:

$$\sigma^* = \sigma\frac{KT}{e_0 z D_0} \quad ; \quad \beta = \frac{D_C - D_A}{D_C + D_A}$$

$$\rho^* = \rho + \beta\sigma\frac{KT}{e_0 z D_0} \quad ; \quad \rho = \frac{X\cdot v\cdot\Delta_0\cdot L}{\frac{\Pi d^2}{4}} \qquad (5)$$

$$D_0 = \frac{2D_C\cdot D_A}{D_C + D_A}$$

ρ - volume density of the electric load

σ - electric conductivity

e_0 - electric load

$D_C D_A$ -cationic and anionic diffusion coefficients

D_0 -average diffusion coefficient

j, j^* -total and conjugated current densities

K- Baltzman coefficient

z- valence

Ψ -electric potential

v-transportation speed

Δ_0 -relative rugosity of the walls

X- F.c.t

C- concentration of molecules

t- time to move the fluid

$A_C = \frac{\Pi d^2}{4}$ - area of the transversal section of the conveyance pipe.

Differential equation which conducts the density of the electric load when a combustible fluid flows is:

$$\frac{\partial q}{\partial t} + v\nabla q + \frac{\sigma_0}{\varepsilon}q - D\nabla^2 a = 0 \qquad (6)$$

In this equation we notice that the contribution brought by each and every term to the quantity of loads $\left(\frac{\partial q}{\partial t}\right)$, to the density of loads due to the convection $v\nabla q$, to the electric migration of the load $\left(\frac{\sigma_0}{\varepsilon}q\right)$ and the diffusion of the load $\left(D\nabla^2 q\right)$. The expression of admissible speed for pumping inflammable liquids through pipes is:

$$v_{\lim}^{1,875} = \frac{1}{8}\cdot\frac{2\cdot 10^7\cdot\varepsilon_{rg}\cdot\nu^{0,875}\cdot n\cdot F}{\chi\cdot\tau_l\cdot\varepsilon_{rl}\cdot R\cdot TS_C^{0,25}\left(1-\frac{C_P}{C_0}\right)}\cdot\frac{S}{d_C^{0,875}} \qquad (7)$$

where:

υ-cinematic viscosity of the liquid

n- 0,5 - transportation number of ions

$S_C = \frac{P_e}{R_e}$ – Schmidt's number; P_e - Pechet's number

R_e - Reynold's number

C_P -ion concentration of the pipe wall

C_0 -ion concentration in the volume of liquid

d_C -pipe diameter

χ -coefficient depending on the nature of load carriers and the degree of the wetness of the pipe walls

$\tau_l = \frac{\varepsilon_0 \cdot \varepsilon_{rl}}{\gamma} \Big/ \left(1-\frac{\alpha}{2}\right)$ -relaxation time of the liquid

$\alpha = \frac{\varepsilon_{rg} \cdot h_f}{\varepsilon_{rg} \cdot h_f + \varepsilon_{rl} \cdot h_g}$ -feeling coefficient of cargo compartment

ε_{rl} -relative permitivity of the liquid phase

Admissible pumping speed of oil products through pipes of 1,23 .... 5 m/s depends on their positioning onboard ship. In the case of orizontal pipes, this speed is at least two times greater than that of a vertical pipe, table no. 1.

Table 1. *- Admissible flowing speed of some hydrocarbonic products*

Hydrocarbonic product	Resistivity	Flowing speed for the bottom pipe (m/s)	Flowing speed for the surface pipe (m/s)	Contents in impurities (g/m3)
air fuel	48	6.62	2.8	
Gasoline 98	58	8	4	
Gasoline 95	60	8.4	4.2	
Special fuel	46	15	5	
Benzene	60	3,6	1.3	40
Dietil bezene	60	1.64	0.48	50-70
Isopropylbenzene	6	5.2	0.72	70-100
Xylen	8.5	6.7	1.4	40
Toluen	8.6	6.8	1.5	40
cyclohexane	460	2	1.2	40

3. Mathematic formulation of the theory of spatial load when hydrocarbonic fluids flow.

As a result of studying fundamental processes, which generate the production of electric loads when transporting oil products, we tried to approximate the nature of the balance existing between the migration ants the convection of the loads on and near the surface of separation. In order to make possible a solution for the partial differential equations written above, we developed a problem in which, knowing the section of a pipe with given dimensions, the problem becomes bidimensional due to the simetry following the cylindrical coordinate φ (fig. 2.) [5-8]

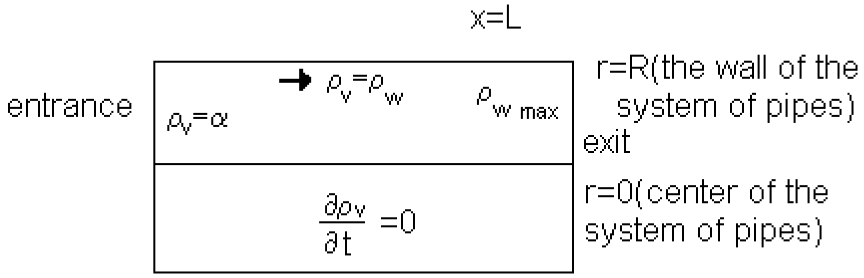

Fig. 2

Limiting conditions are those in the figure an the numerical boundary is chosen in order to completely ignore the flux and the load due to the term $v\nabla\rho_v$ and the boundary load remains unaffected both by the flow of liquid (the load is static) and by the load accumulation in the lower part of the system of pipes.

The equations which govern the density of the load are solved using the numerical method of finite differences. The flow is supposed to be linearly and the speed profile is given by the relation:

$$v = 2v_m\left(1-\frac{r^2}{R^2}\right)\hat{a}_x \tag{8}$$

where: v_m-medium speed of the fluid

R- internal radius of the system of pipes

$\hat{a}_x$-the speed vector of Ox axis (the module of which is 1)

The equation (5) becomes:

$$\frac{\partial\rho_v}{\partial t} + 2v_m\left(1-\frac{r^2}{R^2}\right)\frac{\partial\rho_v}{\partial x} + \frac{\sigma_0}{\varepsilon}\cdot\rho_v - D\left(\frac{\partial^2\rho_v}{\partial r^2} + \frac{1}{r}\frac{\partial\rho_v}{\partial r}\right) - D\frac{\partial^2\rho_v}{\partial r^2} = 0 \tag{9}$$

The low density is approximated on a matrix in time and space and the differential solution is written as follows:

$$\rho^n_{v,jk} = \rho_v\left(j\Delta x, k\Delta r, n\Delta t\right) \tag{10}$$

where: j;k;n - whole values

$\nabla x, \nabla r, \nabla t$ - levels (steps) of the matrix $\nabla x = 0 \div L; \nabla r = 0 \div R$

Depending on the notations, the explicit methods of finite differences in accordance with the equation (10) is written:

$$\left(1+\frac{\Delta t}{\varepsilon}\sigma_0\right)\rho^{n+1}_{v;j,k} = \rho^n_{v;j,k} - 2v_m\left(1-\frac{r^2}{R^2}\right)\frac{\Delta t}{\Delta x}\left(\rho^n_{v;j,k}\rho^n_{v;j-1,k}\right) + \frac{D\Delta t}{(\Delta r)^2}\left(\rho^n_{v;j,k+1} - 2\rho^n_{v;j,k} + \rho^n_{v;j,k+1}\right) +$$

$$+\frac{D\Delta t}{2\rho_{jk}\Delta r}\left(\rho^n_{v;j,k+1} - \rho^n_{v;j,k-1}\right) + \frac{D\Delta t}{(\Delta r)^2}\left(\rho^n_{v;j+1,k} - 2\rho^n_{v;j,k} + \rho^n_{v;j-1,k}\right)$$

where: $\rho_{jk} = k\Delta r$

$$\left.\begin{array}{l}\dfrac{D\Delta t}{(\Delta n)^2}\langle\dfrac{1}{2}\\[2ex] \dfrac{D\Delta t}{(\Delta x)^2}\langle\dfrac{1}{2}\end{array}\right\}\text{conditions (of sufficiency) due to the terms of diffusion}$$

$2v_m\dfrac{\Delta t}{\Delta x}\langle 1$ condition (of sufficiency) due to the term of convection

Limiting conditions are numerically approximated as follows:

- the density of volume of the load where entering the system of tubes is considered to be equal to naught.

$$\rho^n_{v;0k} = \rho_v\left(0, k\nabla r, n\nabla t\right)$$

- the density of volume of the load on the wall of the system of pipes is considered to be equal to the unity.

$$\rho^n_{v;jk} = \rho_v\left(j\Delta x, k_{\max}\Delta r, n\Delta t\right)$$

Newmann's boundary condition in the center of the system of pipes is imposed by establishing the relation:

$$\rho_v; j,-1 = \rho_v\left(j\Delta x, -\Delta r, n\Delta t\right)$$

Whenever it is required in the scheme. The same condition is imposed when we determine the contribution due to the term of diffusion, that is:

$$\rho^{n}_{v;\,jmsx+1,k} = \rho_v\left(\left(j_{\max}+1\right)\Delta x, k\Delta r, n\Delta t\right) = \rho^{n}_{v;\,j\max-1,k} = \rho_v\left(\left(j_{\max}-1\right)x, k\Delta r, n\Delta t\right)$$

4. CONCLUSIONS

Active measures can be taken against the disturbing effects that cause electrostatic discharges in order to prevent the phenomenon of electrostatic charging or passive measures, which constitute proper protection methods.

Norms and recommendations to R.N.R. (Romanian Classification Society) have been settled against electrostatic discharges:

- all pipes user for oil products and inert gas must be earthed to the ship's hull and intervals of 10 m at the most.
- between intermediate flanges there must be an electrical convection to allow the electric load to drain into the ground.
- the initial rate of transport must not exceed 1 m/s until the longitudinal measurements of the cargo compartment haven't been fully covered so as to minimize the mixture with the remaining water and to reduce spraying and the electrical charged fog
- entering the residual tanks of the systems of pipes must be done so as to avoid turbulence and the production of hydrocarbures or emulsion with water.

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