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M. Gacanovic

Static Electricity: Influence of Gas Cavities on Penetration in Vapoury-air Space of the Reservoir

Abstract: The highest density of gas bubbles exists in the area close to the grounded metal wall of the reservoir, partially filled with fluid, e.g. petrol. During originating and vanishing of gas bubbles, there is breaking between bubbles and grounded reservoir metal wall. Those discharging can be manifested as sparking or can produce flaming of present combustible mixtures in vapoury-air space of reservoir (e.g. petrol-vapoury and air). In this way, large accidents produced as explosions and fire can happen. Mechanism of appearing and vanishing bubbles charging and discharging is described in the paper. Part of our results for appearing and vanishing bubbles charging processes realized in petrol facilities reservoirs is also presented in the paper.

Keywords: Static electricity, gas bubbles, petrol industry

I. Introduction

In vapoury-air reservoir space, as well as in the fluid that partially fills the reservoir (in this case petrol), electric field is established. After gas bubbles appearing at the petrol surface, there are electrical forces acting on them. Electrical force is a result of electrical field established in vapoury-air space. Normal component of the force pushes gas bubbles to the top of the reservoir, and as the consequence of tangential component of the force, bubbles are moved to the metal wall of the reservoir.

II. Phenomenon

The largest value of normal electric field component in vapoury-air space exists at the vertical axis of cylindrical reservoir. Tangential component of electrical field has minimal value. As the result, gas bubbles move to the reservoir top. When gas bubbles separate from the petrol surface, they burst. That is the reason of the absence of the bubbles at the part of the petrol surface around reservoir vertical axis.

III. Explanation of the phenomenon

The more the observed surface points are closer to the reservoir wall (which can be, but it is not necessarily grounded), normal component of electrical force decreases, while tangential component value increases. As the consequence, the tangential component "pushes" gas bubbles to the reservoir walls (Figs. 1 and 2). This is more noticeable if the reservoir wall is grounded. The highest density of gas bubbles is established in the area very close to the grounded metal wall. The size of this area depends on reservoir shape and geometry, level of the fluid as well as on the physical and chemical characteristics of the fluid. During appearing and vanishing of gas bubbles, there is breaking between bubbles and between bubbles and grounded wall of the reservoir. Possible discharging between gas baubles at the petrol surface or in vapoury-air reservoir space is a huge risk for technological procedure of decanting and storing of the petrol. Those discharging can be manifested by sparkling, and later can produce flaming of easily combustible mixtures (vapoury: petrol-air) in vapoury-air reservoir space. The discharging in vapoury-air space are much more dangerous than those at the petrol surface. In Figs. 1 and 2 are presented possible ways of discharging, manifested by sparkling between gas bubbles, gas bubbles and water drops, as well as gas bubbles and metal reservoir wall. The charged particles in the fluid can be gas bubbles, water drops or some other charged "cloud" formed from different components. The characteristics of gas babble are intensity of interior electrical field, pressure value, temperature, permittivity of the babble "interior" etc. Above described phenomenon is presented in Figs. 1-4.

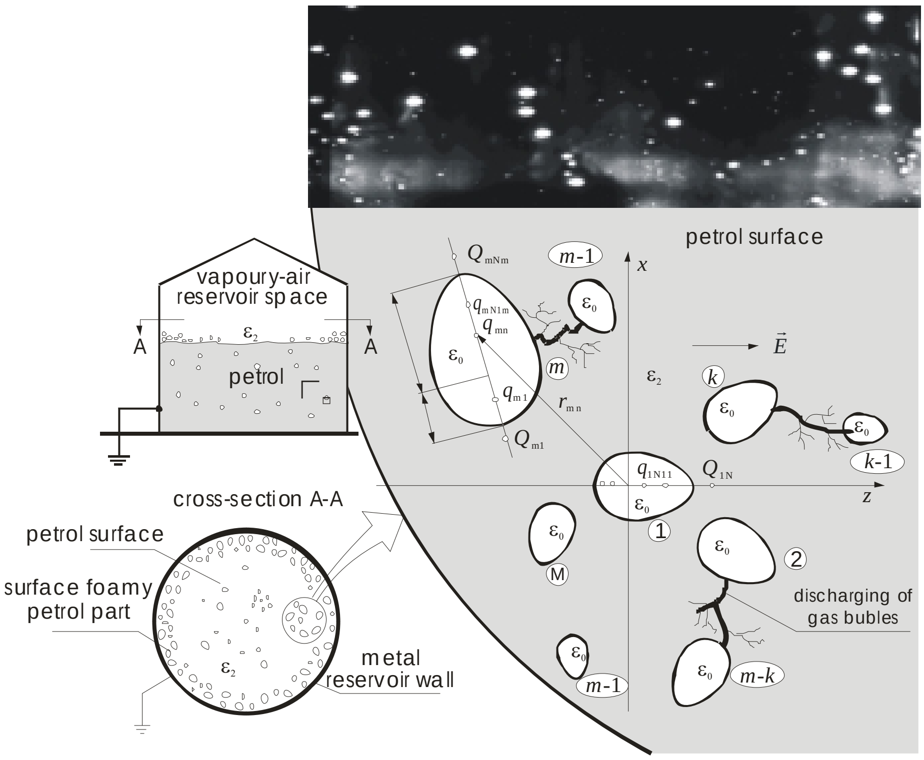

Fig. 1: Illustration of oval gas bubbles at the petrol surface in vertical grounded and partially filled cylindrical reservoir [1].

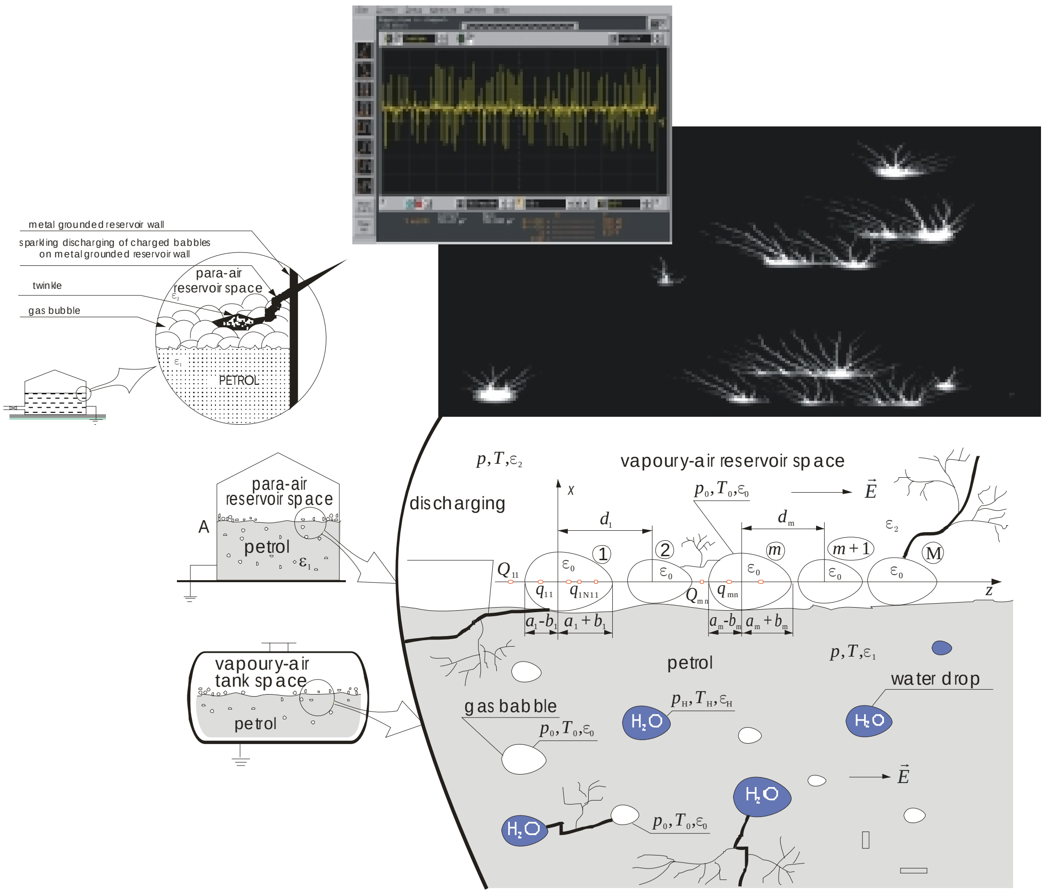

Fig.2: Illustration of possible conditions of oval gas bubbles at the petrol surface and inside the fluid, in partially filled reservoir, [1].

IV. Obtained results

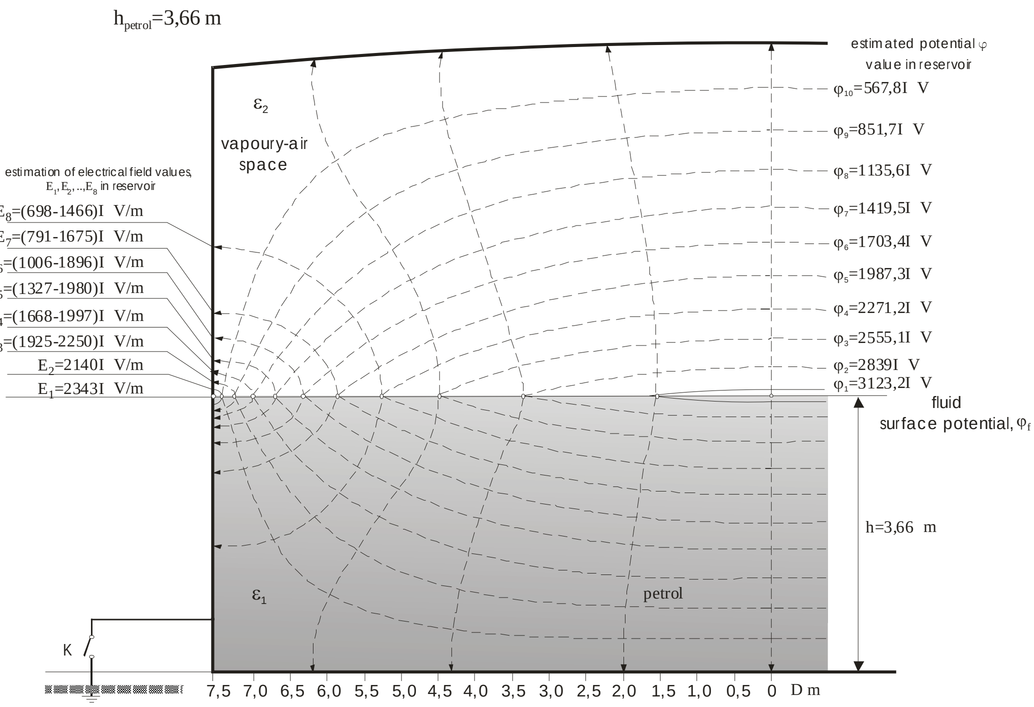

Fig. 3: Numerical estimation of the potential value φ and electrical field E in the reservoir of the basis diameter $D = 15$ m, [1] .

$$I = \pi D j_z l_e \left[1 - \exp\left(-\frac{l}{l_e}\right)\right] = I_\infty \left[1 - \exp\left(-\frac{l}{l_e}\right)\right]$$

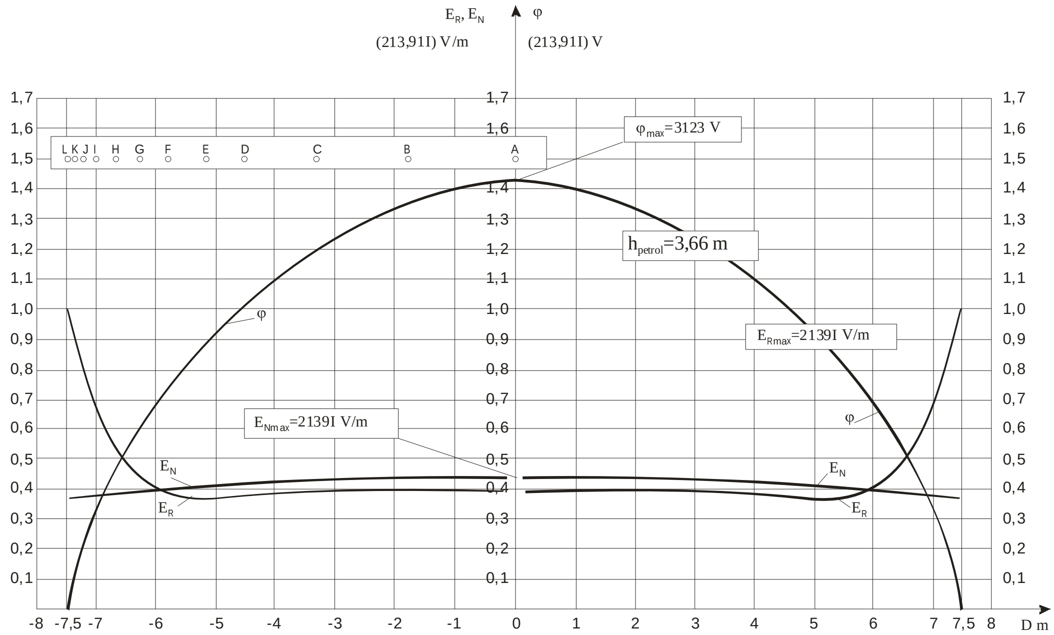

Fig. 4: Numerical estimation of the potential φ , normal electrical field component, E_N , and tangential electrical field component, E_R , in vapoury-air space of the grounded vertical cylindrical reservoir of diameter $D = 15$ m , with petrol level $h = 3{,}66$ m , and capacity of 1000 tones. The coordinate system is positioned as shown in Figure. The expression for current is also given in the Figure. The maximum obtained results are $\varphi_{\max} = 3123{,}2I$ V ; $E_{R\,\max} = 2139{,}1I$ V/m ; $E_{N\,\max} = 956{,}8I$ V/m ; $E_{\max} = 2343{,}0I$ V/m ; where x is the distance from vertical reservoir axis in meters [1] .

V. Theoretical explanation of the phenomenon

The system of *M* oval gas bubbles, having different sizes, placed on the petrol surface in the vertical cylindrical reservoir is observed in electrical field $\overleftrightarrow{E}_0$ that acts on those bubbles, Figs. 1-2. Each babble can be replaced by system of fictitious charges placed on vertical axis of the babble [1]. For example, *m*-th babble is replaced with the system of point charges $q_{mn}, n = 1,2,...,N_m$ in the babble interior and $Q_{mn}, n = 1,2,...,N_m$; ($N_m = N_{2m} + N_{3m}$) in the babble exterior. Charge q_{mn} , with respect to the *m*-th babble exterior, acts as a dipole, and then system of *M* bubbles can be presented as the system formed from *M* dipoles. When the influence of other bubbles (dipoles) is neglected, the dipole moment of the single babble is according to [1],

$$\overleftrightarrow{p}_{om} = \sum_{n=1}^{N_1} \overleftrightarrow{q}_{mn} \overleftrightarrow{r}_{mn} \ . \qquad (1)$$

But, if the real system is observed, mutual influence exists, and equivalent electrical dipole moment can be presented, as in [1],

$$\vec{p} = \vec{\alpha}\vec{E}, \quad (2)$$

where, $\vec{\alpha}$ is polarisation tensor expressed as

$$\vec{\alpha} = \begin{bmatrix} \alpha_{xx} & \alpha_{xy} & \alpha_{xz} \\ \alpha_{yx} & \alpha_{yy} & \alpha_{yz} \\ \alpha_{zx} & \alpha_{zy} & \alpha_{zz} \end{bmatrix}.$$

In expression (2) $\vec{E}$ is electrical field, which is the result of the field in petrol $\vec{E}_0$ and the field of the rest of the dipoles, system except of the observed one. If M is the total number of dipoles, and E_{dk} field of k-th dipole, dipole moment of the m-th system is, [1],

$$\vec{p}_m = \vec{\alpha}_m \left[\vec{E}_0 + \sum_{\substack{k=1 \\ k \neq m}}^{M} \vec{E}_{dkm} \right]. \quad (3)$$

From previous expression it can be concluded that with decreasing of distances between bubbles (cavities) centres electrical field increases because there is vicinity effect. Consequently, there is increasing of electrical field and the condition for discharging is better. There is also influence of the babble shape and size on the discharging effects in vapoury-air space.

Comments

The realized researches [1], were very significant for the analysing of the bubbles establishing process and babble influence on the discharging processes at the petrol surface and in the reservoir.

VI. Conclusion

The gas bubbles on the petrol surface influence on the electrical field increasing in reservoir vapoury-air space. In this way, the discharge risk between gas bubbles and between gas bubbles and grounded metal wall of the reservoir, particularly filled with petrol, became higher

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