NEGATIVE CONSEQUENCES OF CONDENSATE FORMATION IN THE PRESSURE-SEAL FEED-THROUGHS

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Abstract

Methods of controlling the condensate formation in electrical equipment are of particular importance to the deep-sea topics, namely to the ship pressure-seal feed-throughs, whose parts are in different temperature conditions. There are various reasons for the condensate formation in the pressure-seal feed-throughs, including conditions of the pressure-seal feed-throughs installation, the vessel hull sweating and the electrical conductors heating and their subsequent cooling. The article covers the mathematical description of the condensate deposition model in the feed-through feed-throughs, and the events to control this phenomenon.

Keywords: Electrical equipment, pressure-seal feed-through, condensate, condensing point, Mendeleev-Clapeyron law, insulating jacket integrity, capillary effect.

I. Introduction

The electrotechnical personnel, who operates and maintains the working electrical plants and the irelectrical equipment, faces negative consequences of the condensate formation on the electrical equipment pieces systematically. For instance, (from the author’s personal practice) during the rapid temperature change in the engine-rooms of Ganzportal cranes, where the electrical equipment boxes are not heated, fine droplets can be formed on the contacts, and when the moving contacts touch the stationary contacts of the switching equipment, the fine droplets become an ice crust that is a good insulator for electrical current of the control circuits (the control-circuit voltage on the Ganz cranesis 110 V), during the open contactors operation, or the insulation resistance reduction because of sweating of all the electrical equipment pieces. Apart from that, this phenomenon can be observed on the portal cranes quite frequently because they are usually operated in the vicinity of open water, where there are evaporations and high air environment humidity. This shortcoming in the control circuits contacting pairs operation would be eliminated...
through changing the contacting pairs’ spring forces, which would have an effect on the contacts’ mechanical durability at the same time.

Ways of controlling the consequences of the condensate formation in the electrical equipment are well-known and widely used in the electrical engineering. This phenomenon also occurs during laying the power cables in the metallic pipes. Such special methods, as the pipe face sealing, hole making in the pipeline bottom for the condensate out flow are also used on vessels to make impossible the condensate influence upon operating parameters of the networks and, in particular, the cables laid in the pipes.

The pressure-seal feed-through, which is built into the vessel’s main hall and in which the hermetic insert temperature is close to the outboard environment temperature, while the copper insulated conductors are with the room temperature and the conditions that are comfort for the team, and with the high humidity, is a special case. Proceeding from the pressure-seal feed-through condition installation in the vessel hull, the condensate can be formed on such elements of the pressure-seal feed-through as the pressure-seal feed-through plug, nuts, and insulating covers of the conducting cores and the wire harnesses. This is connected with the fact that the condensing point can be on the pressure-seal feed-through elements inside the room. Methods of controlling these phenomena are well-known and widely used in the ship building: special heat sealing mastic is applied to the hull parts, the fitter items and other metal elements including the pressure-seal feed-through. This mastic makes impossible a contact of the pressure-seal feed-through elements with the room’s air environment and assures the condensing point transfer from the pressure-seal feed-through open surface to the heat-sealing coating massif. However, the condensate can penetrate to the pressure-seal feed-through conductors through other ways and channels too.

It was noted that in spite of the heat-insulating coating availability, the vessel hull structure sweat, forming the drops that, as their quantity increases, can flow, including to the pressure-seal feed-throughs conductors. In accordance with GOST 24040-80 and OST 5.6066-76 for protection of electrical equipment, cable passages, harnesses against the moisture, the project documentation must provide for the events making impossible the entry of, among other things, the condensate to the cable passages and the wire harnesses. The condensate can also be formed as a result of the electrical conductors heating and their subsequent cooling.
Fig. 1: Schematic section of the pressure-seal feed-through, where: 1 – the hermetic insert body; 2 – the plug; 3 – the conductors for connection with the internal cable network of the vessel; 4 – the sealing element; 5 – the conducting cores for connection with the external cable network of the vessel; 6 – the compound; \( \overrightarrow{AB} \) – the vector representation of the pressure-seal feed-through.

During the electric current passage via the pressure-seal feed-throughs conductors, the contacts and the wires are heated, which leads to the increase of volume and pressure of the air in the air gaps, which are between the conducting cores wires and the insulating covers, to its displacement from the gaps and its subsequent replacement, during the cooling of the pressure-seal feed-through, with the humid air from the room through the resulting rarefaction. (The humidity does not evaporate from a practically enclosed volume.) This phenomenon follows the Mendeleev-Clapeyron law [I]:

\[
pV_m = RT \quad \text{или } V = \frac{m}{M}RT
\]

where \( p \) is pressure,

\( V_m \) is molar volume,

\( R \) is universal gas constant \((R = 8.3144598 \text{ J/mole} \cdot \text{K})\),

\( T \) is absolute temperature, \( \text{K} \);

\( V_m = \frac{V}{\nu} \) (where \( \frac{m}{M} \) is quantity of gas moles, \( m \) is mass, \( M \) is molar mass).

This ratio, when using the agreed notations, can be written in the following form:

\[
p = nkT,
\]

где \( n = \frac{N}{\nu} \) is atom concentration (the substance atom quantity in the volume unit), \( k = \frac{R}{N_A} \) is Boltzmann constant, где \( N_A \) is Avogadro number.

This writing form bears a name of the Clapeyron-Mendeleev equation (law) [I].
When analyzing the equations, it should be assumed that the condensate moisture is accumulated and deposited slowly, and this depends on quantity of the heating – cooling cycles, the volume of sucked environment, the ambient humidity and other indicators, in other words, the mathematical description of the condensate deposition model is complicated and multifactorial. This explains the length of a process of the pressure-seal feed-throughs failures directly from the operation starting moment to the failure.

When shutting off the electrical current in the pressure-seal feed-through circuits and, later on, when cooling it, the humid air, which fills in the order room, is inhausted, and the moisture from the inhausted air is deposited to cold surfaces of the current-conducting elements of the pressure-seal feed-through (the copper conductors), whose temperature in the pressure-seal feed-through structure area is getting equal to the outboard environment temperature quickly. Then under the action of the force’s gravitational component, the moisture goes down to the insert contact surface and is accumulated gradually in this area. The more cycles of switching-on – switching-off (heating-cooling) of the electrical equipment are carried out, the more moisture is accumulated in the microcavities and the quicker the resistance of insulation of the current-carrying parts of the pressure-seal feed-through is reduced.

In the absence of the capillary effect in the pressure-seal feed-through structure, the moisture is spread under the gravitation laws only in case of departure of the pressure-seal feed-through axis from horizontal, and the pressure-seal feed-through insert must be located below the level of the plane of filling of the pressure-seal feed-through plug with the compound.

While the copper and the organosilicone rubber are submerged into the water, as the laboratory experience shows, the meniscus is absent, since the both surfaces are watered completely, but the surface tension forces are insufficient to raise the water. In other words, the water is not raised on the watered surfaces because a “capillary effect” phenomenon is absent. This explains the absence of failures of the pressure-seal feed-throughs that are located above the axis and have the opposite angle of slope.

Depending on an angle of the pressure-seal feed-throughs installation into the vessel hull in relation to the vessel’s basic plane, it is possible to consider two schemes of possible condensate spread on the pressure-seal feed-throughs elements.

Let’s represent the pressure-seal feed-through in the form of the vector $\mathbf{AB}$, in which the vector beginning with point A is a part of the pressure-seal feed-through, which is located in the main hull, and the vector end with point B is a part of the pressure-seal feed-through that is located in the cable entry body.

a) the hermetic insert is above the plug*
Fig. 2: The vector of direction of the pressure-seal feed-through installation in the vertical plane in relation to the horizontal plane (the vessel axis), where DP is the diametral plane.

Note to Fig. 2: * - the vector arrow characterizes the hermetic insert position in relation to the whole pressure-seal feed-through.

It is also necessary to take into account that location of a place of fault of the insulating covers integrity exerts influence upon conditions of the moisture spread along the insulated conductors that are connected to the pressure-seal feed-through insert. These are mechanical through damages of the insulation as well as possible absence of the insulating jackets hermiticity at the junction of the pressure-seal feed-through wires with conducting cores of the connected cables. In other words, if a place of the insulating jacket fault is above the horizontal axis passing through the bottom edge of the pressure-seal feed-through plug, the condensate moisture penetration to internal contacts of the pressure-seal feed-through will be assured, and, on the contrary, if the insulating jacket fault is below the horizontal axis passing through the bottom edge of the pressure-seal feed-through plug, the condensed moisture, during repetition of the heating-cooling processes, will flow mainly under the action of gravitation forces through the damage into the room environment. This is true of the case if the jacket fault point is not in direct proximity to the bottom edge of the pressure-seal feed-through plug.

II. Conclusions

1. In the high humidity rooms, in relation to the pressure-seal feed-throughs, the protection levels with IP being 55 and 65 are insufficient.
2. The pressure-seal feed-through conductors must have high mechanical impact resistance.
3. The organo silicone rubber must not be used for these structures as electrical insulation, since it has low resistance to various mechanical loads.
4. In order to completely protect the hermetic inserts contact surfaces against the condensation formation, it is recommended to use conducting cores of the waterproof cables whose structure is free from pocked air.

5. Through implementing the presented events, the pressure-seal feed-through protection level can be brought to the watertight construction, when IP is 66 or 67.

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