AIRPORTS AND THEIR INFRASTRUCTURE

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S.V. Boichenko, Cand. Sci. (Eng.)
S.V. Ivanov, Dr.Sci. (Chemistry)

MODELING OF THERMO-ELECTRIC BATTERY'S CALCULATION OF HYDROCARBONS RECUPERATION SYSTEM

Institute of Transport Technologies, NAU, e-mail: ucach@nau.edu.ua

With the maintainability to insure effective work of breathing valve of new generation authors developed thermal model expectation of a design thermo-electric battery, which in some measure of approach describes process of fuel condensation.

Today with the purpose of prevention of natural hydrocarbon fuel losses in tank farm is to place high attention to improvement of the breathing and safety valves of tanks. The purpose of the breathing valve consists in reduction of losses from evaporation and prevention of destruction of tanks. Is established, that even with the serviceable breathing valve during year of a storage at temperature 20°C from the ground tank (50 m^3) evaporates about 400 kg of petrol, and with underground or half-underground – 150 kg [1–7].

On the basis of carrying out numerous researches, analyses of methods and means of prevention of fuel losses from evaporation the breathing valve of new generation (BVNG) is created which constructively unites physical processes of adsorption and condensation by thermoelectric cooling [8; 9].

For an optimum choice of thermo-electric modules (TEM) which are let out serially, the authors have developed thermal model for the calculation of the thermo-electric battery design (TEB) and maintenance operation of BVNG. By development of this model the authors used the theory of similarity, in particular by the third theorem of similarity (Kirpichov-Huhman theorem), which evidences that similar there are processes of one physical nature and have similar one-valuedness conditions and numerically equalled of the certain criteria [10; 11].

For realization of thermal calculation BVNG we shall divide it into three zones (figure):

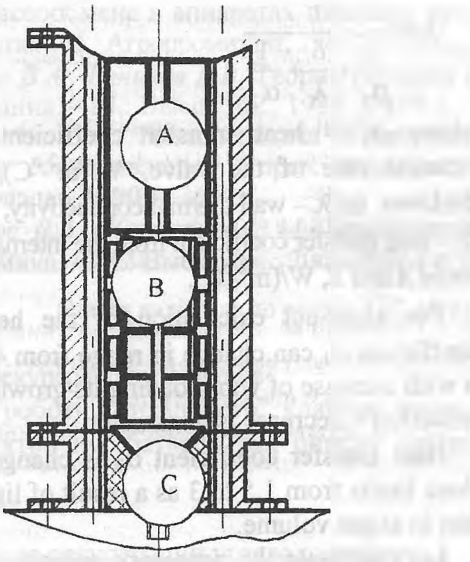
- fuel vapor adsorption zone *A*;
- fuel vapor condensation zone *B*;
- condensate discharge fuel vapor in the tank zone *C*.

On the basis of the theoretical items of information it is possible to generate the following phenomenological model of processes TEB.

Vapor rise from a fuel surface in the tank upwards on elevating channels by a diameter of 12 mm that constructively located on the valve perimeter.

The zone *B* structurally consists of external and internal contours. These contours are designed so, that between them are established TEM that form TEB.

For pressure reduction in a zone *A*, carbon vapors get on an internal surface of a zone B, that is the zone of condensation. Vapors are embossed from the zone *A* in the zone *B* because of a temperature difference between zones. Then they are condensed on an internal surface of the zone *B* (cold side) and flow down in a zone *C* of own weight. The carbon vapors take away heat from an external contour of the zone *B* since effective temperature potential of silica gel makes 40–60°C. Regulation of heating temperature is carried out by regulation of a current size, as $Q_h = f(I)$.



Breathing valve of new generation division plan

Then we shall consider in dynamics processes, which occur in BVNG.

The zones A and B are in a thermal jacket and heat of carbon vapors, which advances on channels, dissipates in an environment. This component is necessary to estimate, as the more thermal diffusion, the more should be the temperature on the hot side TEB. Results are increase of temperature on the cold side which will reduce an overall performance of condensation surface.

Then, heat allocated on the hot side TEB will be:

$$Q_h = Q_\Sigma + Q_d + Q_s, \qquad (1)$$

where Q_h – total heat allocated on the hot side TEB, W; Q_Σ – total capacity for carbon vapors condensation, W; Q_d – heat of carbon vapors dispersion, which advances through channels; Q_s – heat for heating silica gel, W.

But for all that increase of temperature on the hot side TEB on 1–2°C from calculated, we shall permissible consider allowable. In case this condition is not satisfied, there is a necessity for additional heating insulation of the zone A.

For an estimationof Q_d componen we shall take the advantage of dependence:

$$Q_d = k\,F_{\mathrm{AB}}\,\Delta t;$$

$$\Delta t = t_d - t_e,$$

where t_d – temperature of dispersion, °C; t_e – temperature of an environment, °C; F_{AB} – heat-transfer area between the the zones A and B, m^2; k – heat transfer coefficient, W/(m^2·°C).

Heat transfer coefficient is calculated on the formula:

$$k = \frac{1}{\dfrac{1}{\alpha_1} + \dfrac{\delta}{\lambda} + \dfrac{1}{\alpha_2}},$$

where α_1 – heat transfer coefficient from the external side of the valve, W/(m^2·°C); δ – wall thickness, m; λ – wall thermal conductivity, W/(m^2·°C); α_2 – heat transfer coefficient from the internal side of the zones A and B, W/(m^2·°C).

For short-cut calculation of the heat transfer coefficient α_1 can change in range from 4 to 8. That is with increase of wind loading its growth, and with reduction – decrease is diminution.

Heat transfer coefficient α_2 is changed in more close limits from 1,5 to 3 as a result of light convection in slight volume.

Let's estimate the necessary quantity of heat for warming-up the weight of silica gel in the zone A. In the initial period of time the necessary quantity will be:

$$Q_s = C_p \frac{m}{\rho_g} \Delta t;$$

$$\Delta t = t_{\max} - t_e,$$

where C_p – silica gel of specific heat, kJ/kg ; m – weight of silica gel in the zone A, kg; ρ_g – gravimetric density, kg/m^3; $t_{\max}$ – maximal temperature at which effectively there are desorption processes, °C.

Temperature of an environment t_e are sorption processes (that is before switching on power supply for TEB).

After going out on a mode of operation TEB, if sorbent weight of amount of necessary temperature, constituent Q_a will be equalled to zero. An estimation by this constituent necessary for definition of thermo-battery capacity.

From the equation (1) we shall determine necessary heat for carbon vapor condensation, that is constituent Q_a. Toward this end of that purpose we shall accept a sequence of admissions.

In the zone A carbon vapor has temperature potential t_a, that is temperature, at which a desorption process is effective. At the same time we know quantity of fuel vapor for condensation on cold TEB junction. This process will be estimated with constituent G_k. At the same time we allow for properties of different carbons, in particular heat of vaporization (change of phase heat) θ.

Consequently the equation of thermal balance will look like:

$$Q_a = G_k\,\theta. \qquad (2)$$

On the other hand, heat from the zone A should be apprehended heat-exchange interface in the zone B. This heat is possible to estimate by the equation of Newton–Rihman [11; 12]:

$$Q_a = \alpha_a\,(t_a - t_k)\,F_B, \qquad (3)$$

where a_a – average heat-transfer coefficient in the zone B, W/(m^2·°C); t_a – average effective temperature of sorbent in the zone A, °C; t_k – average temperature in a condensation zone, °C; F_{B} – heat-transfer area in a condensation zone, m^2.

Let's describe heat-transfer coefficient α_a in closed space. Free thermal convection arises in this space as a result of density difference $\Delta\rho$ resulting from heterogeneity of a temperature field. In this case basic thermo-dynamic forces are the constants of Archimed and Prandtl:

$$\mathrm{Ar} = \frac{g\Delta\rho L^3}{v^2};$$

$$\mathrm{Pr} = \frac{v}{a_a}.$$

The Archimed constant equality of Grasgoff's constant

$$Gr = \frac{gL^3}{\nu^2}\beta\,\Delta T$$

at thermo-gravimetric convection from the equation (1)

$$\Delta\rho = \Delta\rho\,\beta\,\Delta T,$$

where β – expansiveness constant of medium, 1/K; ΔT – temperature difference, K.

In view of that the physical properties of substances usually concern to average temperature, we accept, that

$$T = \frac{T_a + T_o}{2}.$$

The influence of Grasgoff's and Prandtl's constants is expressed for medium with $Pr \geq 1$ as Reley constant

$$Ra = GrPr,$$

and for environments with $Pr \leq 1$ as product $GrPr^2$. For a vertical wall the characteristic size is height L.

Then for laminar boundary layer:

$$0{,}5 < Pr < 10, \quad Nu = 0{,}55\,(Ra)^{1/4}, \qquad (4)$$

$$Pr \ll 1, \quad Nu = 0{,}755\,(GrPr^2)^{1/4}. \qquad (5)$$

Then, using dependence (4) or (5) it is possible to determine Nusselt constant Nu. Next knowing Nu we shall determine heat-transfer coefficient:

$$Nu = \frac{\alpha_a L}{\lambda}. \qquad (6)$$

From the equation (6) we shall find required value of heat-transfer coefficient:

$$\alpha_a = \frac{Nu\lambda}{L},$$

where λ – thermal conductivity of a carbon condensate.

By determining heat-transfer coefficient α_a, from the equation (3) we shall determine a heat-transfer area in a condensation zone F_B, and from the equation (2) – Q_a.

Consequently, solving the equation (1) we can determine thermal loading on the cold side of TEM. Knowing the characteristics TEM which produce in lots substantial necessary quantity of TEM and form thermo-electric batteries for guaranteeing operations BVNG. At the same time from TEM, which produce in lots we determine nominal current of devices and their voltage. After that, we select power supplies to the battery, or with the elected quantity of TEM we can project the block of electrical device BVNG.

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С.В. Бойченко, С.В. Іванов

Моделювання розрахунку термоелектричних батарей у системі рекуперації вуглеводнів

Розглянуто розроблену з метою забезпечення ефективної роботи "дихального" клапана нового покоління теплову модель розрахунку конструкції термоелектричної батареї, яка описує процес конденсації палива.

С.В. Бойченко, С.В. Иванов

Моделирование расчета термоэлектрических батарей в системе рекуперации углеводородов

Рассмотрена разработанная для обеспечения эффективной работы «дыхательного» клапана нового поколения тепловая модель расчета конструкции термоэлектрической батареи, описывающая процесс конденсации топлива.