METHOD FOR ESTABLISHING WET VAPOUR TITLE THROUGH LAMINATION AND STATIC CONDENSATION

DAMIAN VALERIU

"Dunarea de Jos" University of Galați, Romania

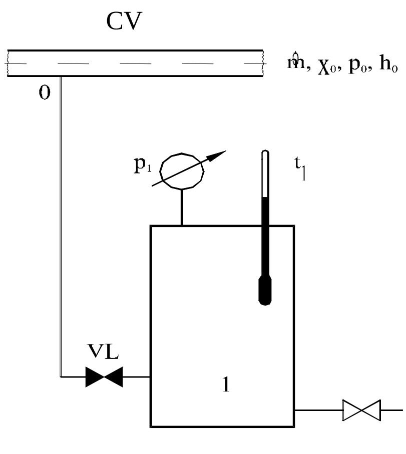
Abstract: This method of establishing the wet vapour title is applied to those consumers of vapour situated at a long distance from the heating station and for which the vapour title is smaller than 0,95. The method will be used when there is no water source on the measurement spot and was applied for the achievement of some energy balances for technological installations in chemical and food industry.

Keywords: vapors title, adiabatic lamination, condensation

1. INTRODUCTION

The use of adiabatic lamination calorimeter to establish the vapour humidity is successful only if humidity is extremely reduced (fig.1).

Technological vapour that is used in food and chemical industry seldom exceeds manometric pressure of 10 Barr, whose correspondent saturation temperature is t_s=184 °C. We can reach saturation throughout adiabatic lamination up to 1 Barr from pressures between 2 and 10 Barr only if the vapour title is between 0,986 and 0,949 (table I).



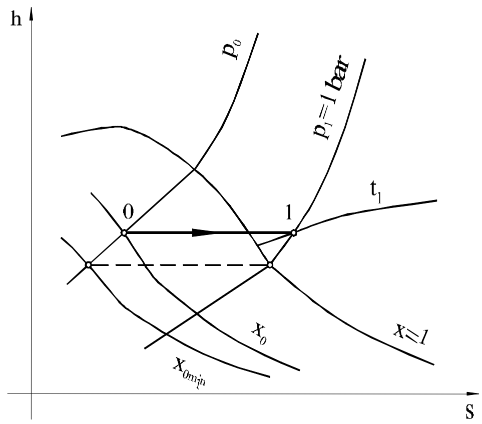


Fig.1. Adiabatic lamination calorimeter method.

It is obvious that for the passage through the overheating zone with a 1 Barr pressure, the vapour title has to be bigger than the values in table I.

In technological installations using saturated vapour, the vapour title can go below the values stated above, for heaters situated far from the heating station. In this case it is not possible to establish the humidity of vapour using the adiabatic lamination calorimeter and another method has to be used.

Minimum title of vapours. Table 1

p [Barr]	t_s [°C]	h' [kJ/kg]	r [kJ/kg]	x_{min}
10	179.9	762.6	2015	0.949
8	170.4	720.9	2048	0.954
6	158.8	670.5	2086	0.961
4	143.6	604.7	2133	0.971
2	120.2	504.8	2203	0.986

2. THE LAMINATION AND STATIC CONDENSATION METHOD

Vapour with unknown state 0 (fig. 2) is first of all laminated adiabatically until it reaches atmospheric pressure (state 1), and then is condensed isobarically until it reaches state 2, of unsaturated liquid.

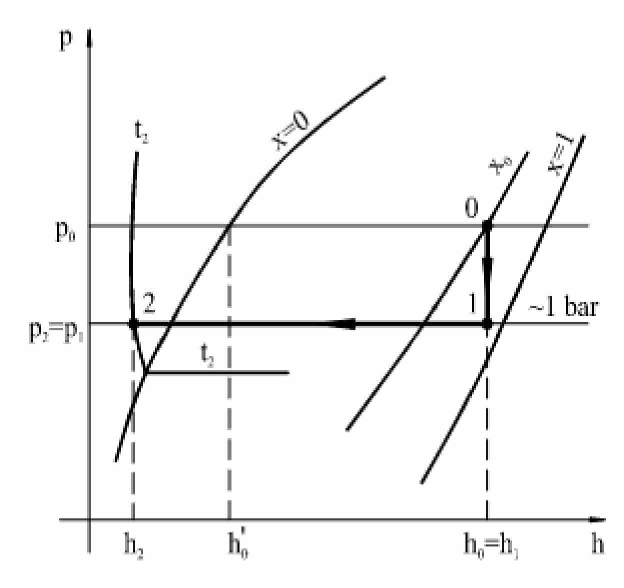


Fig.2 The representation of the process in the p-h diagram.

Knowing pressures p_0, p_1=p_2 and temperature t_2, we can write the following equations:

$$h_0 = h_0' + x_0 \cdot r_0 = h_1 \tag{1}$$

$$q_{12} = h_1 - h_2 = h_0 - h_2 \tag{2}$$

and result the vapour title x_0:

$$x_0 = \frac{h_2 - h_0^{'} + q_{12}}{r_0} \tag{3}$$

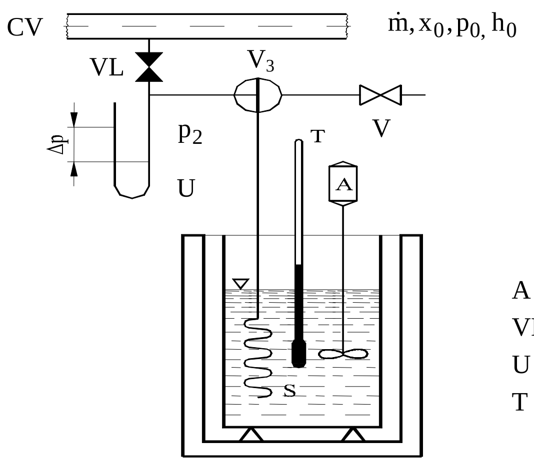
where:

q_{12} – vapors condensation and water under cooling heat;

$h_0^{'}$ – saturated water enthalpy;

r_0 – latent vaporization heat at absolute pressure p_0 in the vapors pipe.

The practical method to solve measurement depends on the presence or absence of the water source on the measurement spot. If the water source for condensation and undercooling exists, there is an easy way to solve the problem, otherwise we can use the method of static condensation in mixture in Berthelot calorimeter (fig. 3).



A - agitator; V_3 - three-way tap;
VL - lamination valve; V - leak valve;
U - manometer; CV – vapors pipe;
T – thermometer; S-coil.

Fig. 3. The scheme of the installation**.**

From the vapour pipe (CV) with an unknown title x_0 we take the quantity m_2 which is laminated (0-1) and condensed (1-2) mixed with the quantity m_1 of water in the calorimeter (with an initial temperature t_1); thus the final temperature of the mixture will be t_e. The vapour lamination will be made until pressure p_2 very close to atmospheric pressure, the difference Δp being indicated by the manometer with U liquid.

Writing down the energy balance equation:

$$(m_1 c + K) t_1 + m_2 h_1 = [(m_1 + m_2) c + K] t_e \tag{4}$$

and replacing $h_1 = h^{'}_0 + x_0 r_0$, the result is the vapors title x_0 in the pipe:

$$x_0 = \frac{(m_1 c + K)(t_e - t_1) - m_2 \left(h_0^{'} - c t_e\right)}{m_2 \cdot r_0} \tag{5}$$

where: K – calorimeter constant (kJ/K);

c= 4,186 (kJ/kg K)- specific water heat.

The linking pipe between pressure plug and the device has to be short, thermoisolated and flexible. Practically this is how we proceed: after having precisely weighed the m_1 quantity of water in the calorimeter, we make a link with the vapor pipe, open the V valve and regulate the V_3 valve in the direction of the passage towards V.

We open a little the lamination valve VL until the manometer U indicates a slight overpressure (a couple of mm on the column of the liquid used), we turn the agitator A on and follow the stabilization of the temperature (t_1). We then make the connection with the calorimeter through V_3 and the vapor will enter the coil until the read temperature is 60÷70°C; after that we turn V_3 towards V again and we stop the vapor from entering the installation through VL. We wait until the maximum temperature is reached on the thermometer, and afterwards we uncouple the installation and establish the quantity of condensable m_2 by precise weighing.

3. ESTABLISHING THE K CONSTANT OF THE CALORIMETER WITH THE ELECTRIC METHOD

We will use an electric heater linked to an electric counter. We introduce the electric heater in to the prepared calorimeter in which there is the m_1 quantity of water, turn the agitator on and wait for the stabilization of the temperature $t_1^{'}$, considered the initial temperature. The electric heater will have an electric supply for a time determined by the value of the temperature at which we want to stop the test; we stop the electric supply and read the consumed energy E on the counter, writing down the maximum temperature ($t_e^{'}$). From the energy balance equation:

$$\left(m_1 c + K + K_i\right) t_1^{'} + E = \left(m_1\, c + K + K_i\right) t_e^{'} \tag{6}$$

the result is the calorimeter constant K:

$$K = \frac{\left(m_1 c + K_i\right)\left(t_1^{'} - t_e^{'}\right) + E}{t_e^{'} - t_1^{'}} \tag{7}$$

where:
K_i [kJ/K]- electric heater constant;
m [kg] water quantity.

4. CONCLUSIONS

This method of establishing the wet vapour title is applied to those consumers of vapour situated at a long distance from the heating station and for which the vapour title is smaller than 0,95. The method will be used when there is no water source on the measurement spot and was applied for the achievement of some energy balances for technological installations in chemical and food industry.

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