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Termodinamically process for atmospheric fresh water production

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Abstract. Since old times, human settlements have been dependent on water, so most localities are located near water sources. The abundance and ease of purchasing freshwater nowadays make us ignore some important aspects of obtaining this indispensable product of life. In addition to traditional water sources, this article highlights a new source, omitted so far, extremely important in disaster conditions, when traditional sources are polluted. It is talking about water contained in atmospheric air (humid air) that can be captured by condensation and contact of humid air with a cold surface that has a temperature less than or equal to the temperature of the dew point. Therefore, the article will develop practical considerations about the humid air parameters, to reduce the energy consumption for obtaining the cold power with the amount of water obtained by condensation.
Keywords: freshwater, thermodynamic, air, dew point, energy

1. Introduction

Humid air, as a source of water in case of emergencies, involves the use of cold surfaces, which are "washed" by humid air, leading to the process of thermal condensation and thus to the accumulation of the product obtained. The problems that arise in such a process are given by the dynamics of atmospheric humid air, so these are both the temperature T and the variable relative humidity φ. Therefore, with the modification of the two elements T, φ and the dew point temperature Tr becomes variable. The calculation program, which is the basis of this work, is to determine the dew point temperature, with a role in optimizing energy consumption, regardless of the source of cold (figure 1), so that the temperature of the contact surface (for condensation) is lower than the dew point temperature. Energy consumption is more important as the energy source is limited in calamity areas and most often depends on environmental factors, requiring an accuracy as high as possible to establish economic consumption, by establishing suitable electricity, in agreement with the temperature required for the condensing surface.[1]

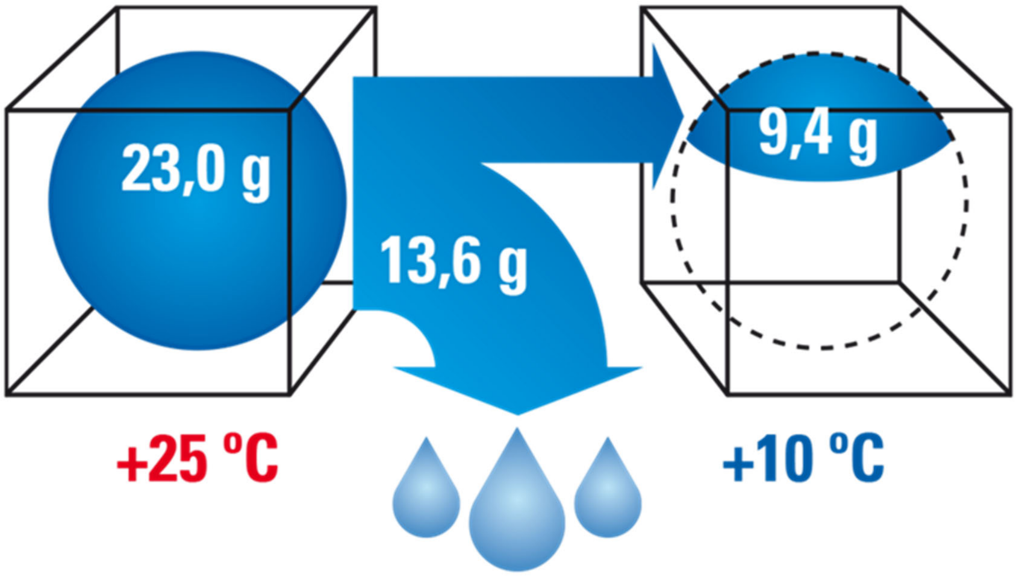

Figure 1. Condensation of moisture in the air

2. Humid air diagram

The humid air diagram (Molliere's diagram) monitors the dependence of the five essential parameters for characterizing the air humidity, namely: dry thermometer temperature, humid thermometer temperature, relative humidity, enthalpy and moisture content. The ability of air to absorb moisture (water vapour) increases with temperature, therefore as the increasing temperature in a closed volume, the relative humidity φ decreases because there is a constant amount of humidity at a higher saturation. For the atmospheric part (open part), the one that interests us, the moisture content increases to the evaporation of the existing water sources in the area of interest and the increase of the ambient temperature. The air saturation curve in humidity is drawn in figure 2 [4].

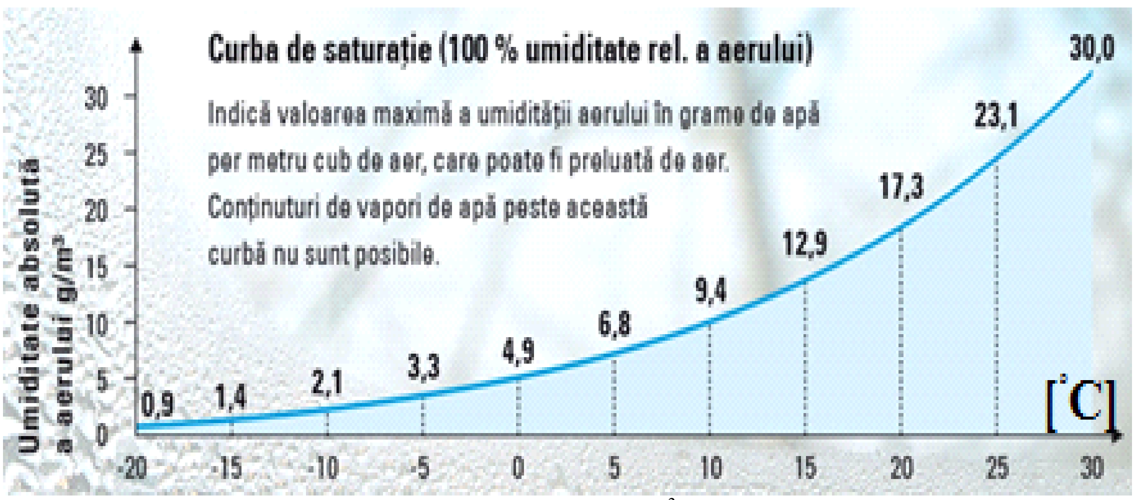

Figure 2. The maximum content of humidity [g/m^3] depending of temperature [°C]

The exponential curve of saturation practically highlights the maximum amount of moisture that can be taken up by a cubic meter of air at a certain temperature and from here we ask the natural question "how low should be the temperature of the condensing surface?" (figure 3). It is obvious that the temperature of the cold source must be lower than the temperature of the dew point, which is obtained at the intersection of the vertical 1-3 'with the maximum humidity zone (point τ1 and corresponding temperature tτ1). The thermal processes in this case are illustrated in the figure 3. From the analysis of thermal processes there are two situations: first, the process of cooling humid air, with thermal transformation 1-3 ', in which the moisture content x remains constant, therefore the phenomenon of moisture condensation in the air does not appear, not being reached by cooling the temperature of the dew point and respectively the second, the process of cooling the humid air, with the thermal transformation 1-2 ', at which the humidity content of the air x decreases (figure 3), which also involves condensation of existing water vapor in humid air. In the first case, the cooling is done in contact with a cold surface whose temperature is higher than the dew point temperature tτ1, against the second case, in which the cold source temperature is t2 (t2 <tτ1). It ask itself the amount of heat that must be eliminated to obtain water from the air by reducing its humidity without being interested in this case the thermal difference between the initial and the final state of the air. In this case, the amount of heat for a kilogram of air is:

$$q_c = i_1 - i_2 \quad \left[{}^{J}/_{Kg}\right] \tag{1}$$

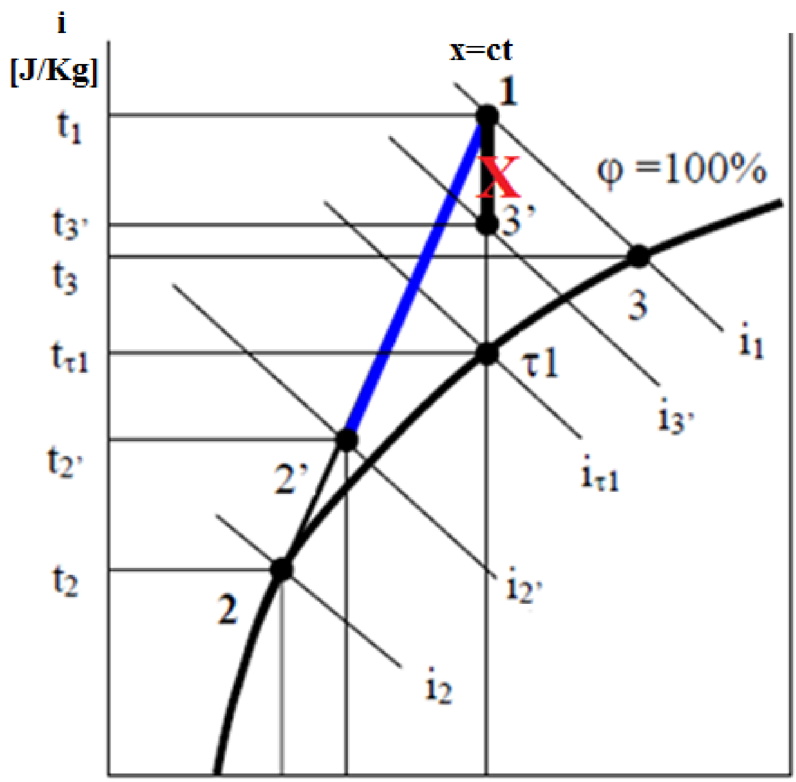

Figure 3. Cooling process of umid air with moisture deposition / with no moisture deposition

3. The system for obtaining water from humid air

Obtaining water from humid air is based on the same principle used by dehumidifiers (figure 4), the difference is the way to obtain the cold surface, which in this case is based on an element that works after the Peltier effect. [2]

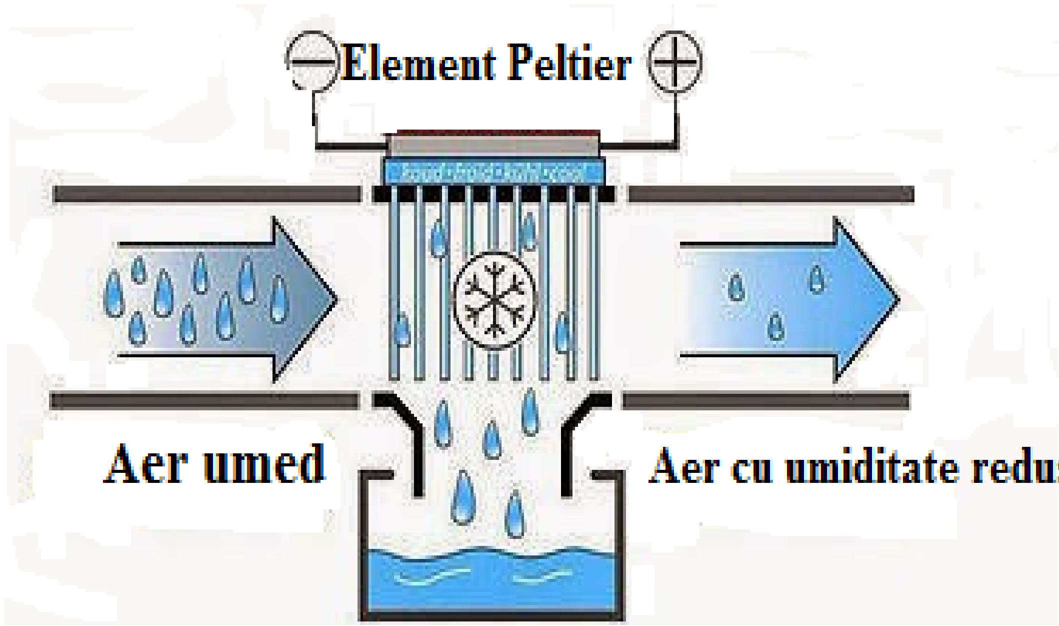

Figure 4. Diagram of the system for obtaining condensing

This constructive desideratum allows the easy supply of the Peltier element from any source of direct current: 12V battery, solar panel, rectified alternative electricity, etc. The problem of the system operation is posed by obtaining a temperature below that of the dew point, to reduce the humidity x in the air, humidity that will be captured to obtain fresh water. According to the figure 2, where it is considered that the temperature of the cold source is t2, the final humidity is x2 ', which induces that for a Kg of humid air is obtained a specific amount of condensation:

$$x = x_1 - x_{2'} \quad \left[{}^{g}/_{Kg\ humid\ air}\right] \tag{2}$$

The amount of condensation is suitable for a heat difference between the cold source and the humid air as t2-t1, while the final air temperature as a result of cooling is t2 '. For the situation in which the cold element is supplied to a direct current source, the problem is to obtain a quantity of condensation as high as possible in relation to the supply voltage and implicitly with the current that will be established at the Peltier element.

4. Load characteristics of the Peltier element as a cold source

The operation of the Peltier element is well known (figure 5) and there are applications for obtaining cold in various refrigerators or refrigerated boxes. To obtain the dew point, the problem is that the dew point is placed in the saturation zone of Moliere's diagram, a low temperature emphasizing an inadequate power consumption. [3]

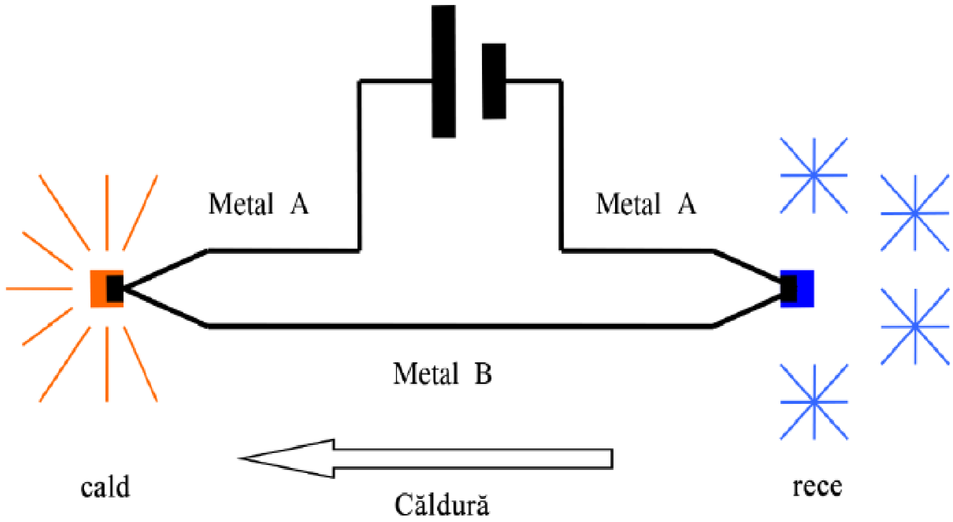

Figure 5. Peltier operation

The problem is to find a way to adjust the supply voltage of the Peltier element so that the temperature of the cold element is not too low and the temperature difference between the work surfaces is too large, which would emphasize the energy consumption. The analysis of Molliere's diagram shows an area of the dew point with a temperature of about 10 °C, at which the maximum moisture content is 9.4 g / Kg of air. Extrapolating the situation on the saturation curve, it is found that an effort to obtain a ΔT = 15 °C leads to the collection of condensation of 13.7 g / Kg of air. At a ΔT = 30 °C it leads to the collection of a condensate of 19.8 g / Kg of air, which is easily seen as a double energy effort, only a 69.19% increase in the amount of condensation is obtained.

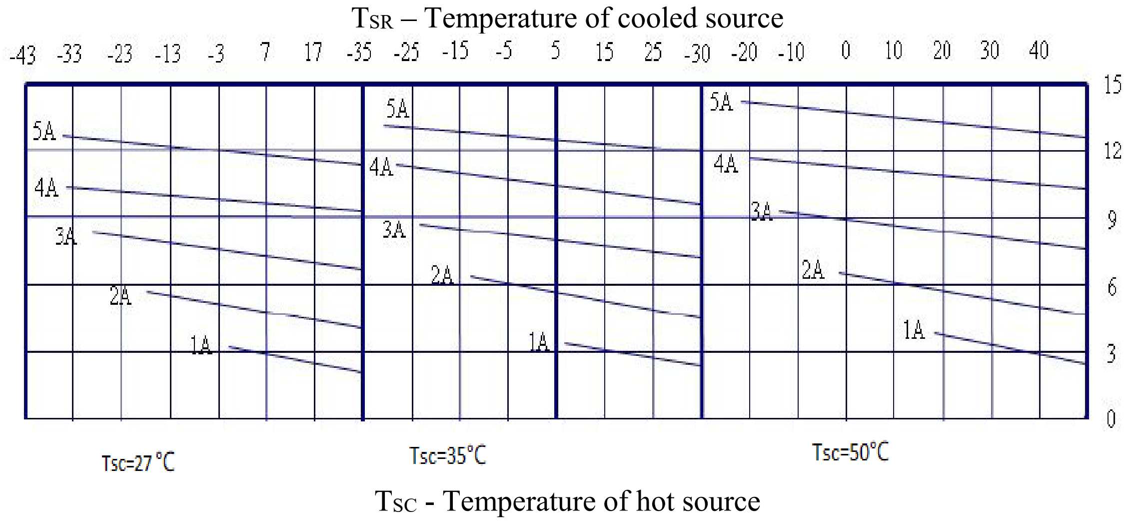

Figure 6. The characteristics of the Peltier element depend on the cooling of the hot surface and the supply voltage

Figure 6 shows that the cooling of the hot surface makes it possible to obtain extreme temperatures of the cold source, up to - 43 °C, which does not make the goal intended of obtaining water from humid air. As a result, this situation is subject to standard operation, without cooling the hot surface and would require additional measures of energy consumption through the use of radiators and forced convection currents. Using the diagram on the right side in figure 6, it can be seen that for a standard Peltier element Thermoelectric Module TEC1-12705T125 that the supply voltage must not exceed 6 V, which corresponds to the requirement already formulated, TSR = 10 °C, that there is a current of 2A and implicitly a 12W power consumption.[4]

5. Performances calculation of the Peltier element

Components used:

- Fan: 12 V, 0.20 A, model 80X80X25, 70 m^3/h = 85.7 Kg/h
- Peltier TEC1-12705, 40 mm x 40 mm x 3,8 mm, 0-6 A, 0-15.2V, max 30W
- Atmospheric temperature T = 15 ^{o}C
- Air humidity = 55 %

Figure 7. Real model with Peltier element

At the inlet of the fan, the temperature of air is 15 °C, the volume of flow is 1.16 m^3/s and moisture content is x = 0.009.
Partial pressure of the water vapor is:

$$p_v = \frac{x \cdot p}{0.6220 + x} \tag{3}$$

The partial pressure of water vapour can be obtained:

$$p_v = \frac{0.009 \cdot 1}{0.6220 + 0.009} = 0.01426\ bar$$

The partial pressure of dry air is:

$$p_{da} = (1 - 0.01426)bar = 0.986\ bar = 98600\ Pa$$

The partial density of dry air is:

$$q_{da} = \frac{p_{da} \cdot M_{da}}{R \cdot T} = \frac{98600 \cdot 0.0290}{8.314 \cdot 273.15} = 1.194\ Kgda/m^3 \tag{4}$$

$$M_{da} = 0.0290\ Kg/mol$$

Thus the mass flow of dry air is:

$$\dot{m_{da}} = q_{da} \cdot \dot{V} \tag{5}$$

$$\dot{m_{da}} = 1.194 \cdot 1.16 = 1.39\ Kgda/s$$

Where q_{da} is the partial density of dry air at the inlet of the fan.

Similarly, for the mass flow of water vapour we have:

$$\dot{m_v} = q_v \cdot \dot{V} \tag{6}$$

$$\dot{m_v} = x \cdot \dot{m_{da}} \tag{7}$$

$$\dot{m_v} = 0.009 \cdot 1.39 = 0.012\ KgH2O/s$$ [5] [6] [7]

6. Conclusions

The paper takes into account the efficient consumption of electricity charged by a direct current source, in the conditions in which the electricity supply network cannot be accessed. There are still solar power supply solutions, but in this case, the amount of water produced, based on air humidity, will depend on the insolation of the catchment area. Thus, in calamity areas, where traditional water sources have been affected, water supply becomes paramount, especially in conditions where roads are impassable and no bottled water can be brought. As such in this case the temperature of the cold source must be monitored, so that this should be obtained based on minimum energy consumption, in this way obtaining the product, fresh water, with minimum energy. After analysing all these aspects, it has been concluded that the thermoelectric refrigeration device can be used for the removal of moisture and water production. It has been further deduced that water production depends on the size of the thermoelectric device. The tool will condense the water present in the atmosphere and then purify it so that it is suitable for human use. During the atmospheric water generator design, requirements were identified to ensure that the research effectively fulfilled its intended purpose. [8]

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