ESTIMATION OF PROSPECTS OF USING PUMPLESS PERIODIC OPERATION ABSORPTION WATER-AMMONIA REFRIGERATION UNITS IN AIR CONDITIONING SYSTEMS BASED ON SOLAR COLLECTORS

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Abstract: The prospects of using heat absorption water-ammonia refrigeration units (AWRU) in air conditioning systems based on solar collectors. A new original design of periodic operation AWRU. A method for calculating such periodic cycles and energy-efficient modes of operation depending on the temperature of the cooling medium, the temperature of the cooling facility, the temperature of the heating source.

Keywords: water-ammonia absorption refrigeration unit, solar collectors

The relevance of research

A necessary condition for operation of compression refrigeration machine is the availability of electrical power. However, under modern conditions the developers of air cooling and air conditioning systems (ACS) seek to use renewable energy sources, in particular solar energy. One of the most promising areas is the possibility of using the existing infrastructure of solar water heaters, the total amount of space that the collectors have in the world is more than 200 million m^2 [1]. Of all the possible types of heat-machines developers tend to opt for sorption chillers — with the solid adsorber (adsorption type) [2,3] or the liquid absorber (absorption type) [4-8].

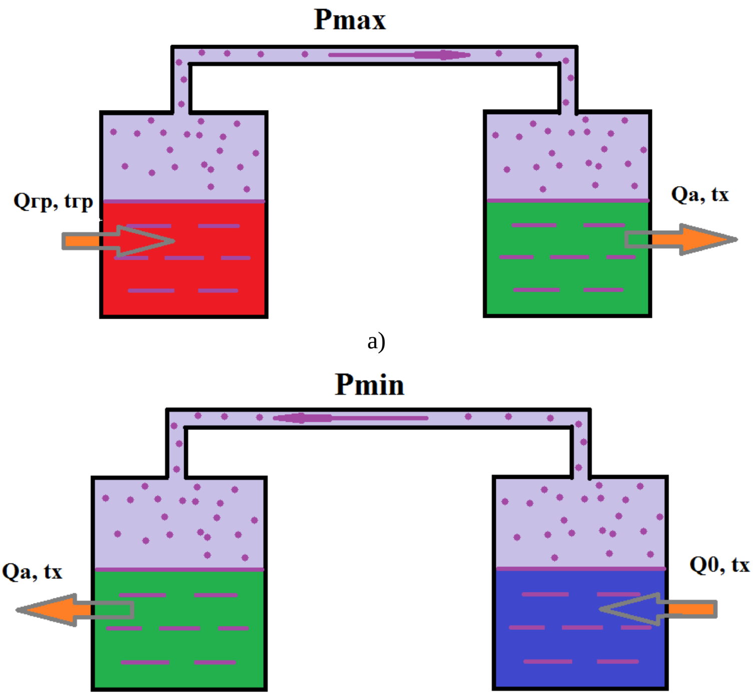
The disadvantages of the modern adsorption [2,3] and absorption schemes [4-8] can be attributed to their reliance on liquid cooling systems of the heat dissipating elements (condenser and absorber), implying the existence of a cooling tower and water expenses for evaporative cooling. Obviously, this makes their usage in arid regions, where there is a water shortage, impractical.

At the same time, among the absorption schemes there can be distinguished absorption refrigeration units (AWRU) that operate with water-ammonia solution as the working fluid and which can be implemented simply enough with air cooling of heat dissipating elements, particularly in the pumpless schemes with inert auxiliary gas [7,8]. It should be noted that in recent years due to the adverse anthropogenic environmental impact of refrigeration systems, more and more attention is paid to the natural refrigerants. Recent documents have clear regulations of use of certain natural refrigerants for different types of chillers: for domestic and commercial refrigerators — propane; for medium-sized refrigerators — carbon dioxide; for large systems — ammonia.

AWRU, unlike their analogues (lithium bromide absorption refrigerators and steam jet cooling units with water as refrigerant), have a broader scope of application, in particular, at negative temperatures down to minus 50 °C. Of particular interest among the various refrigeration systems are water-ammonia absorption refrigeration units of periodic operation (AWRU PO), in which implementation of the refrigeration cycle there are no moving parts of machinery.

The proposed engineering solution and its rationale

A scheme of flows in AWRU PO during different phases of its work is shown in Figure 1 [9]. In the charging period, the heat flux Q_{rp} arrives to the AWRU PO generator at the temperature t_w. In the initial time, when AWRU PO zones are at the same temperatures equaling ambient temperature, the composition of the working fluid (WAS) is the same in both zones. The absorber-evaporator is at ambient air temperature (t_x) and removes the absorption heat Q_a. During the charging period (Fig.1.a), there occurs the movement of mostly lower boiling component (ammonia) from the generator-absorber (G-A) into the absorber-evaporator zone (A-E). Herewith a temperature in G-A is increased from ambient temperature to some temperature t_w, which value is determined by the initial composition of WAS. At the end of the evaporation process, the temperature in the G-A is $t_w \to$ max, the pressure in the system is also at maximum, and the temperature of A-E can be assumed constant and equal to t_x. At the same time, the maximum proportion of ammonia in the WAS is in the A-E, and the minimum — in the G-A.



a)

b)

Fig. 1. The diagram of the heat and mass flows inside the operating AWRU PO
a) – operation during the charging phase; b) – operation during the cooling phase

In the cooling phase (Fig. 1.b), zone G-A goes to ambient environment temperatures, i.e. the heat flow from the heat source is blocked, and the outside air is supplied to the outer surface. Due to the equilibrium shift in the WAS, when the temperature in the G-A is lowered, the system moves into a state of reduced pressures. In the internal volume of AWRU PO, the pressure falls to the minimal (in the initial time) value P_{min}. Saturated with ammonia WAS in the A-E, at this point, begins to boil with heat removal from the outside air flow. Upon cooling of WAS, a thermal flow Q_0 from the environment into the G-A appears due to the temperature difference, that flow is a refrigerating capacity of the AWRU PO. The generated vapor of ammonia is absorbed in the G-A zone with a heat of absorption Q_a transfer to the environment with the temperature t_x. In this process, there is a monotonic increase of pressure with a corresponding increase of temperature in the A-E zone. The air flow that washes over the outer surface of the A-E is cooled to temperatures below the dew point, and the water condensate devaporates out of it. The cooling process takes place until the establishment of thermal equilibrium in zones G-A and A-E.

For the practical implementation of such a device it is necessary to estimate its cooling capacity when operating under different climatic conditions, with the prospect of maximal utilization in the arid tropical zones of the planet. This refrigerating capacity is determined by the amount of heat, removed from air while it cools below the dew point temperature. In connection with this, the initial data will include temperature and humidity of atmospheric air and the potential maximum temperature of the heating source t_w. At the initial stage of the calculation, there was specified an initial equilibrium composition of WAS, denoted as x_{beg} (in the liquid phase) and y_{beg} (vapor phase). When calculating, the volumes of WAS in G-A and A-E zones are assumed equal.

The aim of the thermodynamic calculation of AWRU PO is to define the operating range with the estimation of cooling capacity, which determines the performance of installation for the atmospheric water generation by mechanical dewatering (ensuring the temperature of wall and air contact area is below the dew point).

The calculation was carried out for a range of regime parameters:

- the temperature of the heating source (generator wall) t_w = 65…95 °C;
- the temperature of the "cold" source (ambient air temperature) t_x = 25…45 °C;
- the maximum operating temperature in the cooling area was assumed to be 10 °C.

The analysis of received results shows that an increase in temperature of the heating source reduces the fraction of ammonia in the area of generation, which allows to reach a higher driving capacity of absorption during the cooling phase, i.e. it is possible to increase the cooling capacity of AWRU PO and hence the productivity of atmospheric water generator.

With the ambient air temperature rising, the minimum pressure in the system (for a fixed composition in the area of generation) increases, moreover the increase is higher for larger values of X_{min}. This suggests that the increase in ambient air temperature and pressure rise in the system means the temperature in the cooling area increases too, i.e. the cooling capacity of AWRU PO decreases.

To estimate the cooling capacity of AWRU PO (q_0) in the range of "useful" (the cooling area temperature is not above 10 °C) parameters, there was carried out a calculation of average integral values of the heat of vaporization of ammonia for the operation period of "charge-discharge". It is shown that the cooling capacity increases with the temperature of the heating source. Thus, when t_x = 25 °C and $X_{\min}$ = 0,3, at t_w growth from 65 to 95 °C, q_0 growth is from 650 to 2800 kJ. When t_x = 35 °C, q_0 is increased from 50 kJ to 1200 kJ. When t_x = 45 °C, the operating mode of AWRU PO cannot be implemented at temperatures of the heating medium below 95 °C. At low ambient air temperatures, sufficiently high cooling capacity can be achieved by increasing the amount of ammonia in WAS in the generation area. Thus, similar values of q_0 = 2650 kJ when t_x = 25 °C can be obtained at t_w = 95 °C and X_{min} = 0,3, as well as at t_w = 65 °C and X_{min} = 0,5.

Conclusions

1. By increasing the temperature of heating source, the proportion of ammonia in the G-A zone is reduced, allowing to obtain higher potential capacity of absorption process during the cooling phase, i.e. to increase the cooling capacity of AWRU PO and the performance by water extraction from the air. Since the temperature rise of the heating source from 65 °C to 95 °C, minimal temperature in the cooling area decreases from 7 °C to minus 17 °C.

2. When the ambient air temperature increases, the cooling capacity of AWRU PO decreases, and this tendency is especially noticeable at higher ammonia fraction in the generation area.

3. The performed estimation of cooling capacity of the AWRU PO has shown that it increases along with the temperature of heating source, and at lower ambient air temperatures, this trend is more obvious.

4. At low ambient air temperature, the maximal values of cooling capacity of the AWRU PO can be obtained, by increasing the amount of ammonia in the generation area.

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