MANAGEMENT FOR ENERGETICAL PURPOSES OF THE RECOVERING ENERGETICAL RESOURCES WITH LOW THERMAL POTENTIAL

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1. INTRODUCTION

On of the modernizing methods for the management of the fuel energy in the industrial field is using the recoverable energetically resourses (RER) from the technological processes into the technological proces itself and if possible outside it, for energetically purposes such ast producing hot-water, heating, air conditioning, refrigeration etc.

For technological refrigeration or for confort technological air conditioning the refrigeration plants with vapor compression, which generally use electrical energy, can be replaced with resorbtion refrigerating systems. These systems use directly the industrial RER saving though considerable quantity of fuel and electric energy.

The resorbtion refrigerating systems functioning assume:

– the existence on its neighborhood of a heating source with low potential (RER) and of a cooling user;
– the energetic potential of the RER to be bigger than the neede for the cooling production;
– the simultaneously existence of the heating source and the cooling user.

2. R.E.R. WITH LOW THERMAL POTENTIAL

The resorbtion refrigeration system was designed built and analyzed in terms of using the steam as heating agent for vapor-generator.

As an industrial RER the steam can the useful like secondary steam and exhaust steam.

Exhaust steam:

– source from power machines which use the steam for their driving (forging machines, deep-drawing machines, presses), pumps, compressor etc.
– using area heating, ventilation, air conditioning, hot-water supply of the industrial workshops, administrative buildings and industrial cooling production in absorption-resorbtion systems by using directly the exhaust steam in the vapor-generator.

The recovering functional schemes can be:

– with direct supply (fig.1) for heating, ventilation, hot-water production, for in adsorption-resorbtion refrigeration systems;
– with indirect (fig.2) for heating, ventilation, hot-water production, for in adsorption-resorbtion refrigeration systems.

The preheater 4 warm up the to 80...90°C using exhaus steam at 1,3...1,5 bar, and proheater 6 warm up the water to 130...140°C usine life steam. The advantage of this scheme consist in total collecting of the condensate from the exhaust steam.

Using the exhaust steam for the industrial cooling production in refrigeration systems with resorbtion in industrial area where cooling is needed in summertime and heating on wintertime assure the increase of the annual functioning period of the recovering of the exhaus steam.
The exhaust steam can be wet saturated steam or overheated steam, at relatively low pressure 1.1...2.5 bar. For the power machines the steam flow depends on falling mass having sudden variation (from 0 to 100%). For pumps, compressors and blowers the steam flow has continuous shape with variation in function of the process and of the control method. In order to get uniform flow variations the exhaust steam collector 4 can be used.

**Heat savings.** For the exhaust steam got from the power machines the recovered heat $Q_{rer}$, can be calculated with the relation:

$$Q = D \cdot \Delta h \ [\text{kW}] ,$$

where: $D$ is the exhaust steam flow [kg/s]; $\Delta h$ – steam enthalpy variation [kJ/kg].

**Secondary steam**

– source: from steam generator purge;
– using area: supply water preheating of the boiler heating, ventilation, consumption hor-water production, industrial cooling production in absorption-resorption systems by using directly the exhaust steam in the vapor-generato.

**Using restriction.** The secondary steam resulted from technological processes has a high pressure it doesn’t contain oil marks, but can contain chemical residues.

For saturated secondary steam the recovered heat can be calculated with:

$$Q_{rer} = D \cdot r \ [\text{kW}] ,$$

where: $D$ is the secondary steam mass flow [kg/s]; $r$ – latent heat of condensation [kJ/kg].

3. **RESORBTION REFRIGERATION PLANT**

A resorbtion refrigerating system (fig.3) is made by two vapor-generator, GV and Deg, two adsorbers, Ab and Res, two heat exchangers (economizer), EC1 and EC2 and two solution circulation pumps, P1 and P2. This configuration makes the installation more voluminous and more complicated in comparison with the simple absorption refrigerating system. The main advantage of the resorbtion refrigerating system is the fact that the pressures $p_o$ and $p_r$ from the low-
pressure, respectively, high pressure part of the system, are no longer determined by the vaporizing temperature \( t_k \), and the condensing temperature \( t_k \), as they are on the absorption refrigerating system. The vapor absorption processes in the resorber and the vapor producing process in the degasser can take place at any pressure values, being independent of the temperature. The pressures \( p_0 \) and \( p_f \) can be choosed randomly, especially closer to the atmospheric pressure value. This, problems like tightening, dimensioning, pump construction are simplified and the thermal potential of the heating agent in the vapor generator can be reduced making possible the use of the RER with a lower thermal potential than one used on absorption refrigerating systems.

![Diagram of the resorption refrigeration functional scheme](image)

4. THERMODYNAMIC MODELING

The resorption refrigeration modeling is based on energy conservation equations and the mass conservation equations for resorption refrigeration are:

- **equation of energetic inventory on the Degasser:**

  \[
  \dot{m}_8 \cdot (h_4 - h_8) \frac{\xi_{b2} - \xi_{b1}}{\xi_{b2} - \xi_{s2}} + h_7 - h_4 = \dot{Q}_{0}
  \]

- **equation of material inventory on the Degasser:**

  \[
  \dot{m}_5 = \dot{m}_8 \frac{\xi_{b2} - \xi_{b1}}{\xi_{b2} - \xi_{s2}}
  \]

- **equation of mass inventory on the Degasser:**

  \[
  \dot{m}_7 = \dot{m}_5 + \dot{m}_8
  \]

- **equation of energetic inventory on the Absorber:**

  \[
  \dot{Q}_{ab} = \dot{m}_6 \cdot h_5 + \dot{m}_7 \cdot h_7 - \dot{m}_2 \cdot h_9
  \]

- **equation of material inventory on the Absorber:**

  \[
  \dot{m}_3 = \dot{m}_9 \frac{\xi_{b2} - \xi_{b1}}{\xi_{b2} - \xi_{s1}}
  \]

- **equation of mass inventory on the Absorber:**

  \[
  \dot{m}_2 = \dot{m}_3 + \dot{m}_9
  \]

- **equation of energetic inventory on the economizer EC1:**

  \[
  \dot{Q}_{GV} = \dot{m}_1 \cdot h_2 + \dot{m}_3 \cdot h_6 - \dot{m}_2 \cdot h_9a
  \]

- **equation of material inventory on the GV:**

  \[
  m_1 \xi_{s4} + m_3 \xi_{b3} = m_2 \xi_{b3}
  \]

- **equation of mass inventory on the GV:**

  \[
  m_1 + m_3 = m_2
  \]

- **equation of energetic inventory on the Resorber:**

  \[
  \dot{Q}_{Res} = \dot{m}_4 \cdot h_3 + \dot{m}_1 \cdot h_2 + \dot{m}_5 \cdot h_8a
  \]

- **equation of material inventory on the Resorber:**

  \[
  \dot{m}_1 = \dot{m}_5 \frac{\xi_{b2} - \xi_{s2}}{\xi_{s1} - \xi_{b2}}
  \]
– equation of mass inventory on the Resorber:

\[ \dot{m}_4 = \dot{m}_5 + \dot{m}_1 \]

– equation of energetic inventory on the economizer EC2:

\[ m_4(h_5 - h_{1a}) = m_5(h_{8a} - h_8) \]

– equation of material inventory on the nod A:

\[ \dot{m}_6 = \dot{m}_4 - \dot{m}_7 \]

– equation of material inventory on the nod B:

\[ \dot{m}_8 = \dot{m}_8 + \dot{m}_6 \]

The problem is determined because the number of the equations is equal with the number of the unknowns: \( h_1, h_2, h_3, h_4, h_5, h_6, h_7, h_8, \xi_5, h_{8a}, h_{8a}, Q_F, Q_{Ab}, \text{ and } Q_{Res} + \).

After calculation, we get \( m_1 = m_2 \) and \( \xi_5 = \xi' \), which are essential conditions for continuous functioning of the resorbtion refrigerating system.

The energetic efficiency, \( \eta_{ex} \), is an important criteria of performance evaluation of the resorbtion refrigerating system, because the energies are taken into consideration by the quantity and also by their quality point of view:

\[ \eta_{ex} = \frac{E_{Q_o}}{E_{Q_{GV}}} = \frac{Q_o}{Q_{GV}} \cdot \frac{T_a - T_{om}}{T_{Fm} - T_a} \cdot \frac{T_{Fm}}{T_{om}} \]

where: \( T_{om} \) is the the average boiling temperature of the solution in the degasser zone:

\[ T_{om} = 0.5 \cdot (T_{omi} + T_{om}) \text{ [K]} \]

\( T_{Fm} \) – the average boiling temperature of the solution in the vapour generator:

\[ T_{Fm} = 0.5 \cdot (T_1 + T_6) \text{ [K]} \]

The resorbtion refrigerating system calculation was made under the following condition:

– the refrigeration power of the system \( Q_o = Q_{deg} = 100 \text{ w} \);

– the minimal boiling temperature of the hydroammonia solution in the degasser \( t_{o,\text{min}} = -10^\circ\text{C} \);

– the hydroammonia solution temperature at the absorber, respectively resorber exit \( t_9 = t_3 = 30^\circ\text{C} \).

As variable parameters were considered:

– the heating agent temperature in the vapor generator (RER), respectively the maximum boiling temperature of the hydroammonia solution \( t_F = t_6 = 90...150^\circ\text{C} \);

– the boiling pressure of the hydroammonia solution \( p_F = 8, 9 \) and 10 ata, on the condition \( p_F, p_{k} \);

– the degassing zone \( \Delta \xi \), determined by the temperature variation in the degasser, \( \Delta t_{D} = = 4...12^\circ\text{C} \).

In order to make calculation, it was used a set of equations that describe the thermodynamic model of the \( \text{H}_2\text{O} \text{ – NH}_3 \) binary mixture. These equations were integrated in oroginal softwarw. The advantage of using this model is given by the high evaluation accuracy of the state points, comparing with the using of the common method with the \( h – \xi \) diagram, were the reading accuracy of the values is relative.

The calculation were made for \( p_F = 9 \text{ ata} \), taking into consideration that the heating agent temperature of the vapor generator is more important than the maximum wpok temperature in the refrigeratong system.

The result obtained for each variant of calculation previously mentioned allowed the underlining of the tendencies of the proportions calculated after modifying some parameters considered as variable.

For the performance evaluation of the resorbtion refrigerating system are presented performance coefficient, \( \text{COP} \) (fig.4). Depending on the boiling temperature, the performance coefficient present a maximum around the value of 96°C after which it uniformly decreases.

\[ \text{Fig. 4. COP in function of the boiling temperature and the degassing zone: } t_k = 30^\circ\text{C}; t_o = -10^\circ\text{C}; p_F = 9 \text{ ata}; Q_o = 100 \text{ kW}. \]

**CONCLUSIONS**

This paper presented an adaptation of the resorbtion refrigerating installation following the thermodynamic model of the resorbtion refrigerating
cycle and thermodynamic model of the $\text{H}_2\text{O} - \text{NH}_3$ binary mixture for the purpose of improving it at the design level. The adaptation effort has been justifiable since we managed to influence the main proportions according to the design parameters currently used when calculating these types of refrigerating system. In addition, there have been identified a minimum number of „requirements” for the refrigerating cycle in order for this to be able to work within the designed parameters and with acceptable values for the performance coefficient. The thermodynamic model of the $\text{H}_2\text{O} - \text{NH}_3$ binary mixture, once completed, allows the studying of different types of absorption thermodynamic cycles with the purpose of improving their efficiency.

REFERENCES


[4] LIR, Thermodynamic and physical properties $\text{NH}_3$-$\text{H}_2\text{O}$, 1994.


