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A. Ruciński, A. Rusowicz
The Institute of Heat Engineering - The Warsaw University of Technology,

THE COMPARATIVE ANALYSIS OF SINGLE AND MULTI-EFFECT ABSORPTION COOLING MACHINES

Описані результати розрахунку коефіцієнта корисної дії абсорбувальних охолоджувальних утановок, а також представлено охолоджувальні установки багатокатної дії з сукупністю характеристичних робочих параметрів.

This paper reports on the results of calculation of cooling machine absorption coefficients of performance as well as presentation of multi effect cooling machines with set of characteristic working parameters.

1. Introduction. The raising problem of fossil fuels economic usage is the subject under scientific and commercial consideration. The main problem is how to use the coal, LPG, oil in economic and safety way for natural environment. It is strongly connected with the energy saving by recovering of waste heat from combustion exhaust, waste hot water or steam. This is a step to energy, heat and “cool” production linking - cogeneration (trigeneration). The suitable tools are absorption cooling machines which thanks to waste heat or renewable energy sources produce chilled water for cooling applications. Absorption cooling machines are characterized by a lot of advantages. A very few moving parts give a long life time of the absorption machine with plain service (once per 55000 hours of work). Then a low exploitation costs are noticed with parallel higher investment costs in comparison with compressor refrigeration and cooling. The compact structure is important with one or two shells. The wide range of construction materials used to heat and mass exchangers is considered too. Moreover easy regulation of cooling capacity from 10 to 100 percent thanks to microprocessor controls. Wide range of cooling capacity from part of kW to MW. Unfortunately, the great dimensions, usually the great weight and much space need are disadvantages.

2. One – stage absorption cooling machines. On the basis of mathematical model of an one-stage absorption cooling machine [1, 2] the calculations were executed and the profile of influence of chosen parameters on cooling efficiency was done. The basic assumptions are [3]:

- The steady state refrigerant is pure water.
- There are no pressure changes except through the flow restrictors and the pump.
- At points 1, 4, 8 and 11, there is only saturated liquid.
- At point 10, there is only saturated vapour.
- Flow restrictors are adiabatic.
- The pump is isentropic.
- There are no jacket heat losses.

The scheme of absorption cycle is presented in the Figure 1 with assing of the most important devices and parameters in theoretical absorption investigations. Then the working parameters are analyzed with diagram presentation

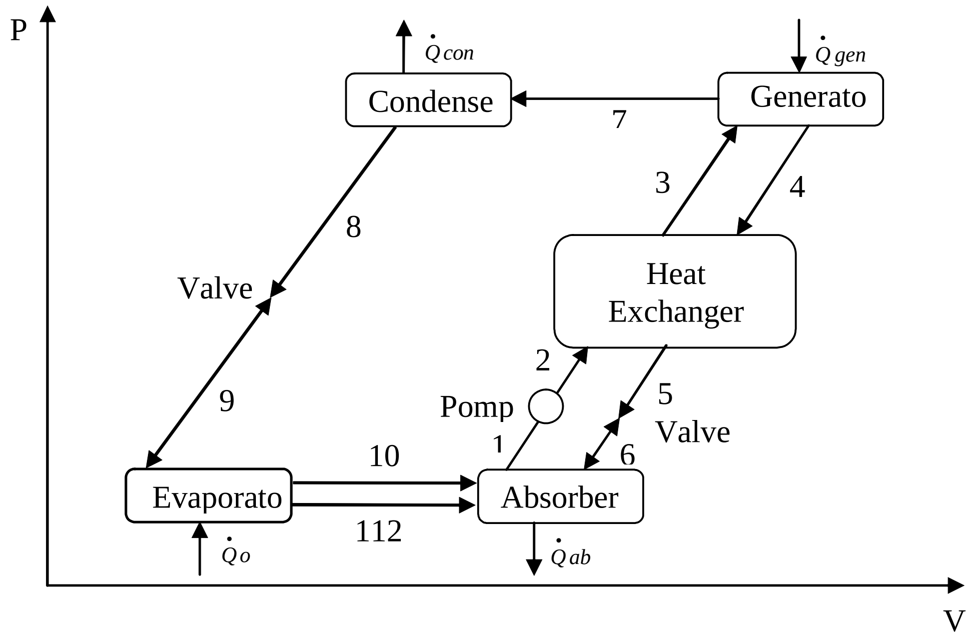

Fig. 1. The diagram of one-stage absorption cooling machine cycle

2.1. The influence of LiBr solution weight concentration into absorber on COP, the solution temperature out of absorber and solution mass flow (Fig. 2).

The input data for calculations:

- Cooling capacity, $Q_o = 10$ kW
- The evaporation temperature, $t_{10} = 6$ °C
- The weak solution temperature $t_4 = 90$ °C
- The weak solution mass fraction, $\xi_4 = 60$ %
- The outlet temperature of weak solution (heat exchanger), $t_3 = 65$ °C
- The condensation temperature, $t_7 = 85$ °C
- The mass flow fraction of liquid refrigerant, $m_{11}/m_{10} = 0{,}025$

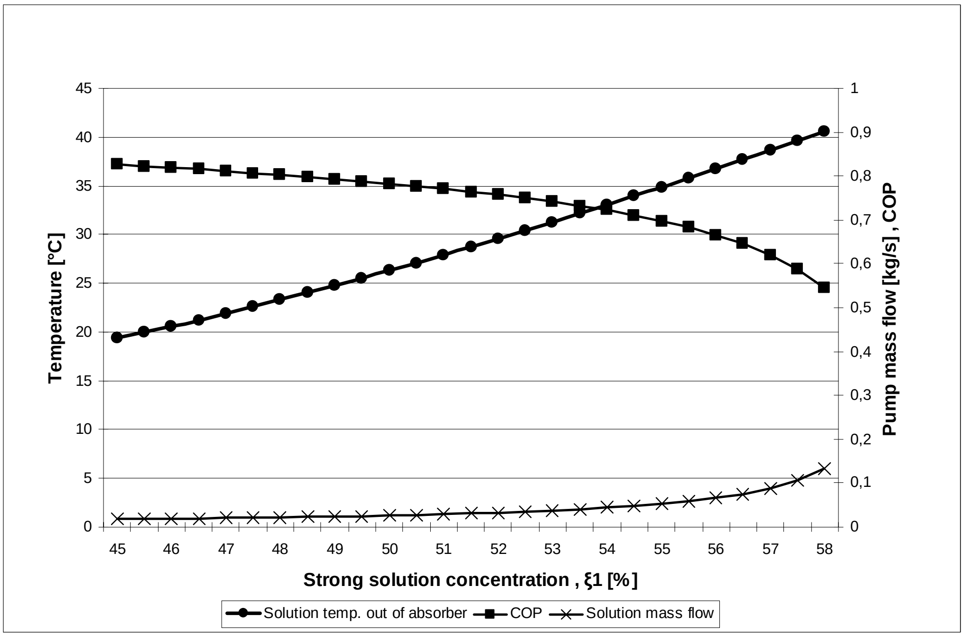

Fig. 2. The infuence of the rich solution on COP, the solution temperature out of absorber and solution mass flow

2.2. The influence of rich solution temperature after generator on COP and pressure in generator (Fig. 3).

The input data for calculations:

- Cooling capacity, $Q_o = 10$ kW
- The evaporation temperature, $t_{10} = 6$ °C
- The strong solution mass fraction, $\xi_1 = 55$ %
- The weak solution mass fraction, $\xi_4 = 60$ %
- The outlet temperature of weak solution (heat exchanger), $t_3 = 65$ °C
- The condensation temperature, $t_7 = 85$ °C
- The mass flow fraction of liquid refrigerant, $m_{11}/m_{10} = 0{,}025$

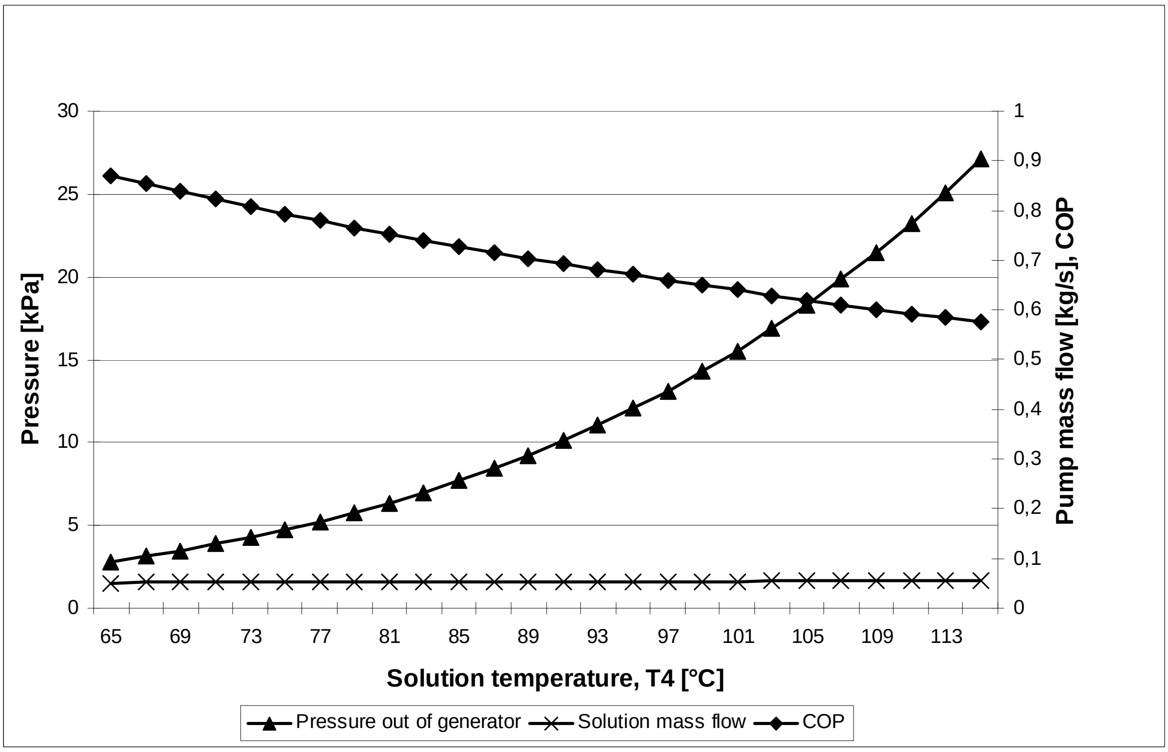

Fig. 3. The influence of rich solution temperature after generator on COP and pressure in generator

2.3. The influence of weak solution concentration on COP and outflow pressure in generator (Fig. 4).

The input data for calculations:

- Cooling capacity, $Q_o = 10$ kW
- The evaporation temperature, $t_{10} = 6$ °C
- The weak solution temperature $t_4 = 90$ °C
- The strong solution mass fraction, $\xi_1 = 55$ %
- The outlet temperature of weak solution (heat exchanger), $t_3 = 65$ °C
- The condensation temperature, $t_7 = 85$ °C
- The mass flow fraction of liquid refrigerant, $m_{11}/m_{10} = 0{,}025$

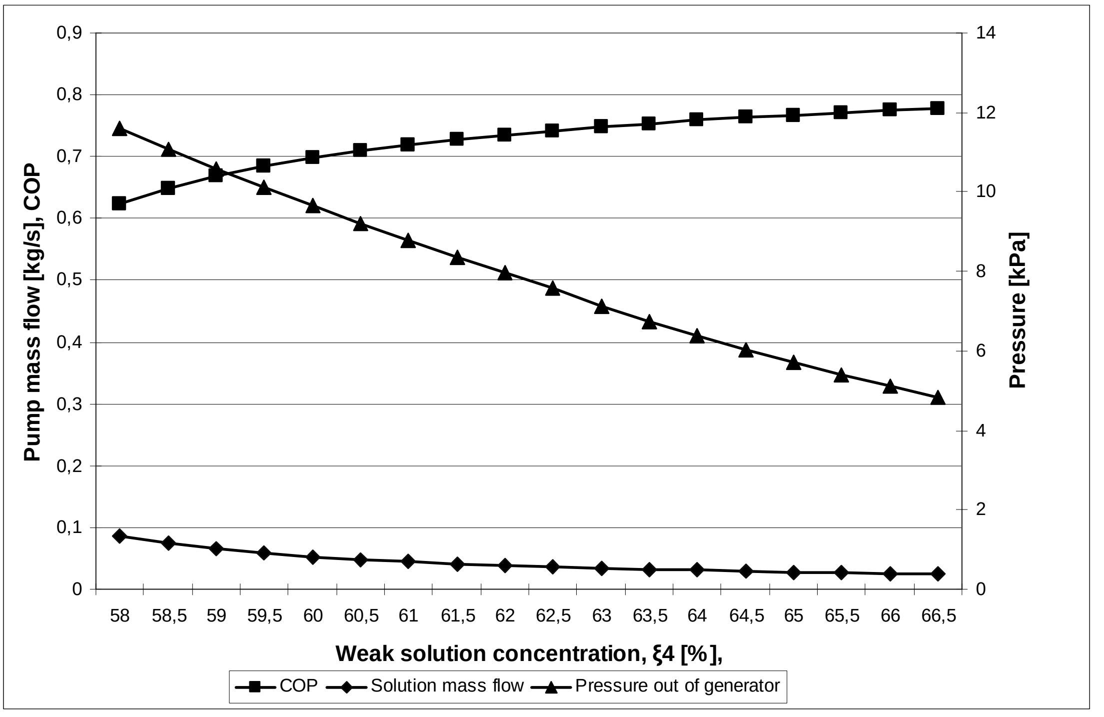

Fig. 4. The influence of weak solution concentration on COP and outflow pressure in generator.

3. Double – stage absorption cooling machines. The introduction of double-stage absorption refrigeration machines projects with the increase of the coefficient of performance on the level 1.2 [4]. However the temperature of the heating agent of high-temperature desorber considerably grows up to the level over 120°C. The whole system of the cooling machine goes to the further development for additional heat and mass exchangers, fitting and systems of the monitoring. Then both the capital cost of such plant and the degree of the complication of the installation grow up. The advantage of such solution is the utilization of low-temperature source of the warmth for low-temperature generator (desorber) coming from eg. solar collectors.

The LiBr – water absorption cooling machine is investigated (Fig. 5). The cooling power Q_o = 174 kW. It is used to prepare a chillled water for air-conditioning system. The average temperature of evaporation is 4.1°C. The device is supplied with water under pressure - the temperature about 180°C. Other sources as a water steam, combustion gases are possible too. Below the scheme of the machine is presented with values of chosen parameters.

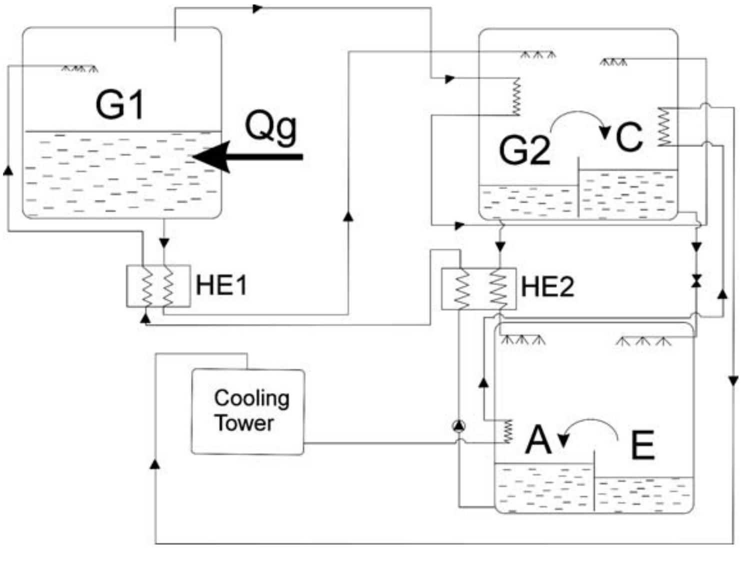

Fig. 5. A scheme of a double –stage series cycle absorption cooling machine. [5]

Table 1

The chosen parameters of examined double-stage cooling machine. [5]

Exchanger	Power [kW]	Pressure [kPa]	Temp. [^oC]	Weig. Conc. [%]
Evaporator E	174,0	0,8	4,1	0,0
Generator G1	124,2	97	165,0	62,0
Generator G2	127,0	7,5	40,3	65,0
Condenser C	168,0	7,5	40,3	0,0
Absorber A	130,2	0,8	4,1	58,5

The analysis of above model was done according to chilled/cooling water level and cooling capacity change. The influence of these on COP is presented in the Figure 6.

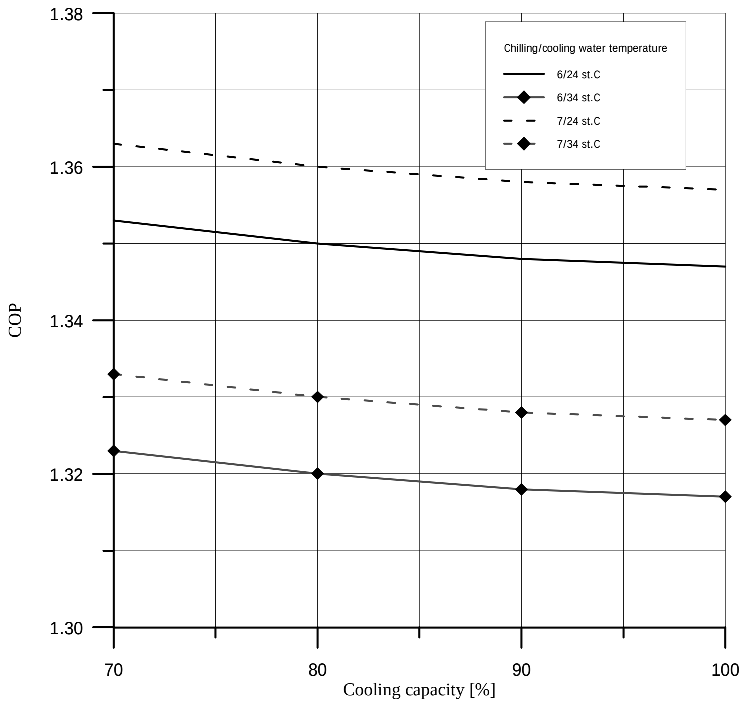

Fig. 6. The influence of cooling capacity change on COP.

4. Triple – stage absorption cooling machines. The concept of building multi-stage absorption cooling machine is an increase of coefficient of performance (COP). Better recovery and flow of heat is the main cause of higher efficiency of absorption cycle. In the Fig. 7 the outline of triple-stage absorption cooling machine is presented. The three generators G1, G2, G3 are mentioned where G1 is the driven one.

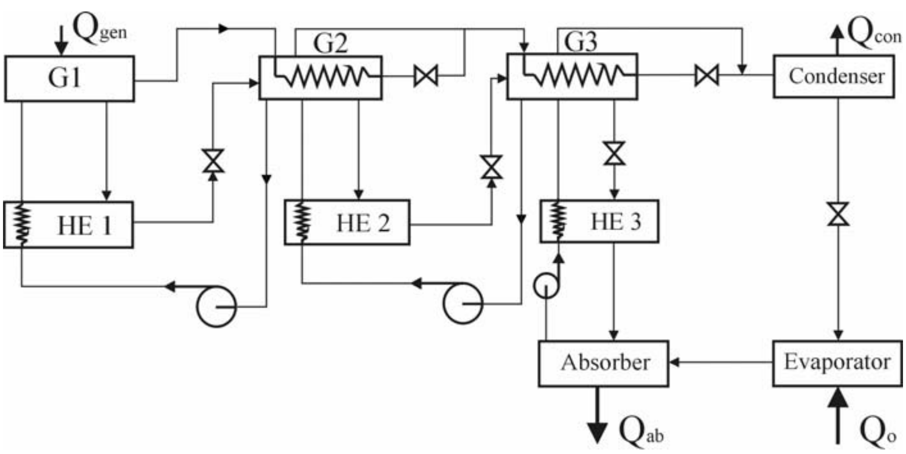

Fig. 7. A scheme of triple-effect absorption cooling machine. [6]

The example data is presented in Table 2. The coeficient of performance is high – 1.6. This value is connected with great level of cooling capacity which could be taken into consideration.

Table 2

The experimental values of working parameters of choosen triple-effect absorption chiller

Lp	PARAMETER	**Unit**	**Value**
1	Cooling capacity	kW	527,4
2	The chilled water inlet temperature	^oC	15,0
3	The chilled water outlet temperature	^oC	7,0
4	Mass flow rate of chilled water	m^3/h	56,7
5	The coolant inlet water temperature at absorber	^oC	32,0
6	The coolant outlet water temperature at absorber	^oC	37,0
7	Mass flow rate of coolant	m^3/h	146,0
8	LPG usage	Nm^3/h	25,77
9	Coefficient of Performence	---	1,6

5. Conclusions. The main interest in absorption cooling technology is connected with adventages as environment friendly substances used, a few moving parts installed (except pumps), waste energy application and trigeneration systems building. According to examinations presented in this paper the main conclusion could be observed: more stages results on better coefficient of performance.

However, some problems should be dissolved (i.e. to high driven fluid temperature) - researchers are still on their way to find the solvation. The hope is to widen the usage of absorption cooling machine in energy sector.

1. Chua H.T., Toh H.K., Malek A., Ng K.C., Srinivasan K.: A general thermodynamic framework for understanding the behaviour of absorption chillers. International Journal of Refrigeration, 23, 2000, p. 491-507. 2. Kim D.S., Infante Ferreira C.A.: Analytic modelling of steady state single-effect absorption cycles. International Journal of Refrigeration, 31, 2008, p. 1012-1020. 3. Florides G.A., Kalogirou S.A., Tassou S.A., Wrobel L.C.: Design and construction of a LiBr-water absorption machine. Energy Conversion and Management, 44, 2003, p. 2483 – 2508. 4. Mahone D.: Absorption Chillers GUIDLINE. New Buildings Institute November. USA, 1998. 5. Rusowicz A., Ruciński A.: The analysis of application of the double-stage absorption refrigeration machines. Proceedings of the XII th International Symposium on Heat Transfer And Renewable Sources of Energy. Szczecin – Międzyzdroje, 2008. 6. Srikhirin P.: A review of absorption refrigeration technologies. Renewable and Sustainable Energy Reviews, 5, 2001, p. 343-372.