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Termodinamična analiza procesov z bogato nasičenimi raztopinami voda-amoniak v absorpcijskih toplotnih napravah

A Thermodynamic Analysis of the Strong-Solution-Saturation Process in Water-Ammonia Absorption Thermotransformers

Tatjana Morosuk

Rektifikacijski proces pri absorpcijskih toplotnih napravah voda – amoniak je energijsko in snovno potraten. Cilj raziskave je vodenje rektifikacijskega procesa na način, ki zagotavlja zmanjšanje porabe energije.

Povečanje področja razplinjanja v toplotnem kompresorju je eden od načinov, kako doseči zgoraj navedeni cilj. To ima za posledico povečevanje koncentracije bogate raztopine. Del bogato nasičene raztopine je izpostavljen dodatnemu nasičenju. Ta del teče v deflegmator skozi raztopinski prenosnik toplote. Proces nasičenja poteka v dodatnem absorberju ali v inverznem rektifikatorju. Z dodatno nasičeno bogato raztopino močno intenziviramo proces rektifikacije v deflegmatorju.

V prispevku je avtorica raziskovala procese nasičenja v pomenu termodinamične analize procesov na temelju različnih procesov dodatnega nasičenja raztopine. S to metodo je logično razvrstila področje uporabe dodatnega absorberja in inverznega rektifikatorja. Poleg tega je shematično prikazala idejne rešitve toplotnega kompresorja, ki so odvisne od možnosti enega ali več hladilnih sredstev. To dovoljuje široko uporabo zraka kot hladilnega sredstva.

(Ključne besede: pretvorniki toplotni, raztopine voda – amoniak, rektifikacija, absorpcija)

The rectification process in water-ammonia absorption thermotransformers is both energy and material consuming. The aim of this research is to conduct the rectification process with reduced energy consumption.

Expansion of the thermochemical compressor's degazation zone is one way in which we can achieve lower energy consumption; but the process requires an increase in the strong-solution concentration. A part of the strong solution is exposed to full saturation, and this part goes into the dephlegmator, beyond the solution heat exchanger. The process of saturation occurs in an additional absorber or inverse rectificator. The use of a fully saturated strong solution greatly enhances the rectification process in the dephlegmator.

The processes of saturation were investigated by thermodynamic analyses of the cycles and schemes. This method arranged the rational fields so as to be able to use the additional absorber or inverse rectificator. In addition, it is shown that the schematic solutions of the thermochemical compressor depend on the presence of one or several cooling media. This means we can use air as a cooling medium.

(Keywords: thermotransformer, water-ammonia, rectification, absorption)

0 UVOD

V sedanjem času je prehod k naravnim delovnim snovem življenjska resničnost. Zato so absorpcijske hladilne naprave vedno pogosteje predlagane za uporabo kot toplotne črpalke različnih zmogljivosti in temperaturnih ravni. Zasnova optimalnih delovnih razmer pri procesih in oblik konstrukcij naprav za izvedbo teh procesov pridobiva vedno bolj na veljavi.

0 INTRODUCTION

The transition to natural working fluids is a reality. As a result, absorption machines are increasingly being used as heat pumps of various capacities and with various temperature levels. Consequently, the definition of the optimum conditions for the processes and the construction of equipment corresponding to these processes has become important.

Konstrukcija novih generacij absorpcijskih naprav voda – amoniak temelji na povečanju delovnega področja in posebno na izvedbi inverznega rektifikacijskega postopka ([1]) ter na uporabi zraka kot hladilnega sredstva.

Eden od osnovnih parametrov postopka v absorpcijskih toplotnih pretvornikih je obtočno razmerje *f*. Glede na sliko 1 ga lahko zapišemo:

The creation of a new generation of water-ammonia absorption machines is based on the expansion of the degazation zone and, in particular, on the realization of the inverse rectification processes ([1]) and the use of air as a cooling medium.

One of the basic characteristics of the thermodynamic cycle of absorption thermotransformers is the solution-circulation ratio:

$$f = \frac{\xi_D - \xi_A}{\xi_R - \xi_A} \quad (1),$$

kjer imenovalec pomeni razliko koncentracij v absorpcijski hladilni napravi:

where the denominator represents difference of concentrations in a degazation zone:

$$\Delta\xi = \xi_R - \xi_A \quad (2).$$

Koncentracija hladiva na vstopu v kondenzator absorpcijskega toplotnega pretvornika dosega vrednosti ξ_D= 0,995 do 1,000 ter tako v osnovi ne vpliva na *f*. Koncentracija revne raztopine ξ_A je določena s temperaturo toplotnega vira in je torej konstantna za določen temperaturni režim (T_{heat} je podana). Koncentracija bogate raztopine ξ_R se lahko spreminja v širokem področju, odvisno od izbrane sheme. Primerno je torej analizirati samo področje razplinjanja $\Delta\xi$.

Povečanje področja razplinjanja v absorpcijski napravi pomeni povečanje koncentracije bogate raztopine ξ_R. Znano je, da je zračno hlajenje naprav manj učinkovito kot vodno, zato je pomen ξ_R toliko večji. Torej je nujno, da zagotovimo možnost umetne širitve delovnega področja v absorpcijskih napravah, kjer uporabljamo zračno hlajenje.

Rektifikacija je eden od temeljnih procesov v absorpcijskih toplotnih pretvornikih z delovno dvojico voda – amoniak. Popolnost obratovanja ter učinkovitost naprave je odvisna od izbire rektifikacijskega sistema.

Altenkirch [2] je predlagal hlajenje deflegmatorja z delom nasičene bogate raztopine, ki je dovedena neposredno iz absorberja. V tem primeru sta deflegmator in rektifikator združena v eno napravo Posredno se poveča učinkovitost raztopinskega prenosnika toplote.

Legi točke 3 kot hladne točke in točke 1 kot točke nasičene kapljevine (sl. 1 do 4) sta optimalni stanji raztopine prenosnika toplote.

Blier [3] je nadaljeval Altekirchovo zamisel in je tudi predlagal uporabo dela bogate raztopine za hlajenje deflegmatorja, s tem da to raztopino prej dodatno nasitimo s paro iz ločevalnika. Dokazal je, da se optimalni delovni režim rektifikatorja prikazuje z razmerjem kroženja nasičene bogate raztopine v rektifikatorju φ, ki je razmerje količin raztopine stanja 10 in dobljene čiste pare, ki teče v kondenzator stanja 5. Primer φ=1 se nanaša na $q_D=\Delta h$ (sl. 2 do 4).

The concentration of refrigerant on the inlet of the condenser of the absorption thermotransformer reaches ξ_D= 0.995 to 1.000, and therefore it does not have an influence on *f*. The concentration of the weak solution, ξ_A, is determined by the temperature of the heat source, as a result, it is constant for a certain temperature range (T_{heat} is given). The concentration of the strong solution, ξ_R, can change over a wide range, depending on the chosen scheme. Thus, it is only necessary to analyze the degazation zone, $\Delta\xi$.

The expansion of the degazation zone is the increase in the concentration of the strong solution, ξ_R. It is known that the air cooling of devices is less effective than water cooling, and therefore the value of ξ_R is more important. So it is necessary to provide ways for the artificial expansion of the degazation zone in the absorption machines which use air as the cooling medium.

Rectification is one of the basic processes of absorption water-ammonia thermotransformers, and the efficiency of the operation and the effectiveness of the machine depends on the choice of the rectification system.

Altenkirch [2] proposed cooling the dephlegmator with the part of the strong solution that is supplied directly from the absorber. In this case the dephlegmator and rectificator are joined in a single unit. At the same time, the efficiency of the solution heat exchanger is raised.

The positions of point 3, for the cold liquid, and point 1, for the saturated liquid, (in Figs. 1 to 4) are in the optimum range for a solution regeneration heat exchanger.

Blier [3] continued Altenkirch's idea and proposed that the part of the strong solution used for cooling the dephlegmator be additionally saturated with the vapor from the separator. He proved that the optimum working range of the rectificator consists of the circulation ratio of the strong solution in the rectificator φ (where φ is the ratio of the quantities of the solution (10 in Figure 1) and the obtained cleared vapor going into the condenser (5 in Figure 1)). The case of φ=1 corresponds to q_D=Δh (Figs.2 to 4).

Povezava procesa rektifikacije in deflegmacije ob dodatnem nasičenju bogate raztopine izhaja iz avtorjevih prejšnjih del [4] in [5].

The correlation of the rectification-dephlegmation process with the additional saturation of the strong solution from the absorber has already been presented [4] and [5].

1 NASIČENJE V DODATNEM ABSORBERJU

1 SATURATION IN AN ADDITIONAL ABSORBER

1.1 Prvi primer (Slika 1)

1.1 The first case (Figure 1)

Nasičenje bogate raztopine v dodatnem absorberju se lahko izvede, če je ne hladimo v osnovnem absorberju. V tem primeru je tlak nasičene raztopine višji od tlaka v osnovnem absorberju ($p_S \equiv p_A$', kjer je p_A'>p_A).

Če izvedemo nasičenje bogate raztopine v dodatnem absorberju, lahko zapišemo toplotno bilanco *i* tega absorberja po enačbi:

The additional saturation of the strong solution in the additional absorber can be carried out if the second source of the cooling medium is absent in the basic absorber. In this case the process of additional saturation of the solution is carried out at a pressure above that of the basic absorber ($p_S \equiv p_A$', where p_A'>p_A).

If the saturation of a strong solution occurs in the additional absorber the thermal balance for *i*-th absorber can be expressed as:

$$q_{Ai} = (f - 1)(h_{Ai} - h_{Ri}) + x_i (h_D - h_{Ri}) \qquad (3),$$

kjer so:

- x_i – največji delež pare hladiva, ki se lahko absorbira v *i*–tem absorberju,
- h_{Ai}– entalpija revne raztopine na vstopu v *i*–ti absorber,
- h_{Ri}– entalpija bogate raztopine na izstopu iz *i*–tega absorberja,
- h_D – entalpija pare hladiva na vstopu v *i*–ti absorber, ki prihaja iz uparjalnika ali *i*–tega separatorja.

Para hladiva, nastala v uparjalniku, se absorbira v osnovnem absorberju. Točka 4 na sliki 1 pomeni konec absorpcijskega procesa. Specifični masni tok raztopine je enak *f*. Tega razdelimo na dva dela (*f*-φ) in φ. Količina (*f*-φ) v celoti (ali delno po Altenkirchu [2]) teče v rektifikator, delež bogate raztopine φ pa vodimo v dodatni absorber, kjer jo dodatno nasitimo.

Dodatno nasičenje bogate raztopine se izvaja s paro hladiva, ki nastane ob ekspanziji v ventilu na *i*–tem tlačnem nivoju. Količina pare, ki nastane pri ekspanziji v ventilu, je enaka:

where:

- x_i – is the quantity of refrigerant vapor that can be absorbed in the i-th absorber;
- h_{Ai}– is the enthalpy of the weak solution on the inlet of the i-th absorber;
- h_{Ri}– is the enthalpy of the strong solution on the outlet of the i-th absorber;
- h_D – is the enthalpy of the refrigerant vapor on the inlet of the i-th absorber, coming from the i-th separator.

Thus the refrigerant vapor formed in the evaporator is absorbed in the basic absorber. The end of the absorption process is at point 4 in Figure 1. The specific solution flow is equal to *f* (point 4). Further, the specific flow *f* is divided into two parts: (*f*-φ) and φ. The quantity (*f*-φ) participates in the regenerative heat exchange completely (or partially according to Altenkirch [2]). The specific flow of the strong solution φ is directed to the additional absorber for further saturation.

Additional saturation of the strong solution is carried out with the refrigerant vapor formed in the throttle to the i-th level of pressure ($p_K<p_i<p_O$). The quantity of vapor formed in the throttle is equal to:

$$z_i = (h^l_{(i-1)} - h^l_i)(h^v_i - h^l_i)^{-1}[1-(x_I + x_{II} + ... + x_{i-1})] \qquad (4),$$

kjer sta:

- h^v_i– entalpija nasičene pare *i*-te dušilne stopnje hladiva,
- h^l_i – entalpija nasičene kapljevine *i*–te dušilne stopnje hladiva.

Obstajajo tri možnosti razmerja med absorbirano količino pare z_i in količino x_i, ki je potrebna za popolno nasičenje:

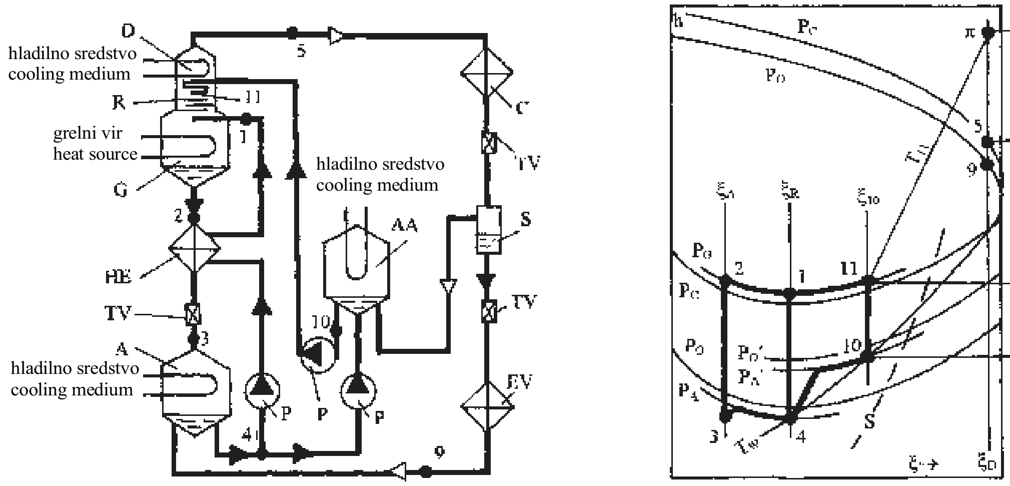
- $z_i < x_i$ – proces nasičenja ni končan;
- $z_i = x_i$ – proces nasičenja je končan;
- $z_i > x_i$ – proces nasičenja je končan, poleg tega so potrebni dodatni ukrepi za absorpcijo preostale pare ($z_i - x_i$).

where:

- h^v_i – is the enthalpy of the saturated vapor of the i-th refrigerant throttling stage,
- h^l_i – is the enthalpy of the saturated liquid of the i-th refrigerant throttling stage.

There are three possibilities for the ratio between the quantity of received vapor z_i and the quantity x_i, which is necessary for saturation:

- $z_i < x_i$ – the saturation process is not complete;
- $z_i = x_i$ – the saturation process is complete;
- $z_i > x_i$ – the saturation process is complete and additional measures are also required for the absorption of the rest of the vapor ($z_i - x_i$).



Sl. 1. *Shema in obtok sistema z dodatnim absorberjem - prvi primer*
Fig. 1. *Scheme and cycle of the system with additional absorber - first case*

Točka 10 pomeni konec procesa nasičenja bogate raztopine (ξ_R) v dodatnem absorberju, ki je v našem primeru hlajen s hladilnim sredstvom pri temperaturi okolice.

Proces med točkama π-5 (desno na sliki 1) je postopek deflegmacije. Odstraniti je treba toploto $q_D = h_\pi - h_5$ za izvedbo deflegmacijskega procesa, kar naj bi po Blierju [3] storili z nasičeno raztopino. Zaradi prenosa toplote se bogata nasičena raztopina segreje v deflegmatorju do točke 11 (nasičena kapljevina), zaradi prenosa snovi pa se odvije proces deflegmacije - rektifikacije. Optimalni režim procesa nasičenja je dosežen ob enakosti $h_\pi - h_5 = h_{11} - h_{10}$. Z 1 kg pare, nastale v generatorju (π-5), dobimo $\varphi = q_D/\Delta h$ (kg) nasičene bogate raztopine 11.

V tem primeru je celotna toplota za deflegmacijski proces odvedena z bogato raztopino. Iz procesa je razvidno, da krivulja S povezuje točke, ki ustrezajo popolni pokritosti tokov ($\varphi = 1$).

Če prihaja do neenakosti $h_\pi - h_5 > h_{11} - h_{10}$, je količina pare hladiva pri srednjem tlaku ($p_S = p_A$') omejena. Ta količina pare ne daje možnosti doseganja koncentracije bogate raztopine (točka 10) na krivulji S. To nas sili k uporabi dodatnega hlajenja deflegmatorja. Hlajenju z bogato raztopino je dodano še hlajenje z okolico (T_w) (na primer hladilno vodo).

Izbira optimalnega števila absorpcijskih stopenj in primernega srednjega tlaka je navedena v literaturi [6].

1.2 Drugi primer (Slika 2)

Del pare iz deflegmatorja vodimo nazaj do dodatnega absorberja, kjer jo pred vstopom dušimo do tlaka (P_A'). Tako dosežemo pogoj

Point 10 represents the end of the saturation process (ξ_R) in the additional absorber, which in this case is cooled by a cooling medium.

The process π-5 (on the right in Figure 1) is a dephlegmation process. It is necessary to remove the heat $q_D = h_\pi - h_5$ for realization of the dephlegmation process. This heat should be removed with a saturated solution [3]. Thus a strong saturated solution will be heated up in the dephlegmator to point 11 (saturated liquid) owing to heat transfer, and the rest of the dephlegmation-rectification process will be carried out by mass transfer. The dephlegmation heat, q_D, as part of the generation heat, will be removed to the generator.The optimum regime of the saturation process is described by the equation $h_\pi - h_5 = h_{11} - h_{10}$. If 1 kg of vapor is formed in the generator (π-5) we gain $\varphi = q_D/\Delta h$ kg of saturated strong solution at point 11.

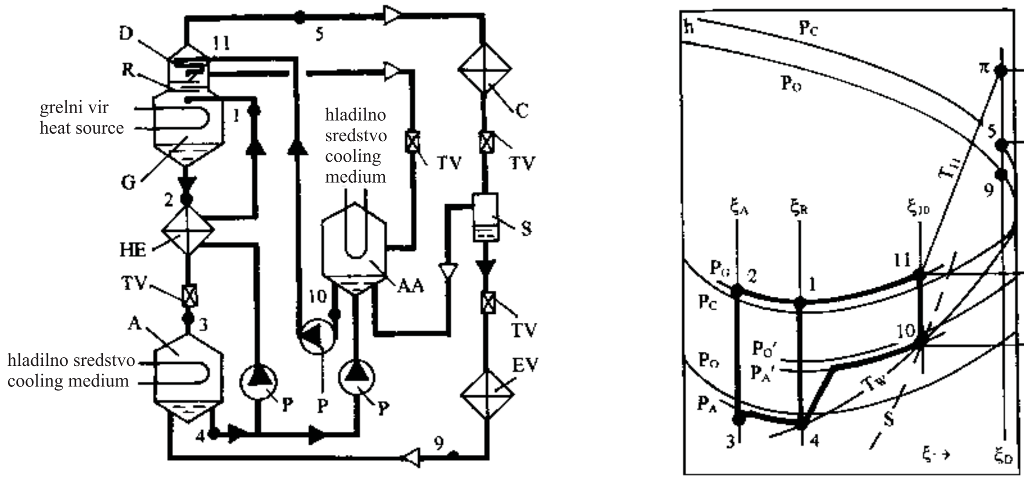
In this case the full dephlegmation heat is removed by a strong solution. It is clear from the cycle that the curve S determines the points set which satisfies the equation of full heat capacities of the flows ($\varphi = 1$).

If the inequality: $h_\pi - h_5 > h_{11} - h_{10}$ is present in the process the quantity of the refrigerant vapor at intermediate pressure ($p_S = p_A$') limited. This quantity of vapor does not provide the possibility of finishing the concentration of saturated solution (point 10) on the curve S. These facts force us to use two cooling processes in the dephlegmators: cooling with a strong solution and cooling with the environment (T_w) (cooling water, for example).

The choice of the optimum number of absorption stages and the appropriate intermediate pressure were reported previously [6].

1.2 The second case (Figure 2)

The high-pressure vapor (p_G) part is selected on the inlet of the dephlegmator and is throttled to the intermediate pressure (p_A') and further directed to the additional



Sl. 2. *Shema in obtok sistema z dodatnim absorberjem - drugi primer*
Fig. 2. *Scheme and cycle of the system with additional absorber - second case*

$z_i = x_i$, kar pomeni da se koncentracija nasičene raztopine poviša do pogojev, ki jih označuje krivulja S. V tem primeru ne nastopa okoljsko hlajenje deflegmatorja.

absorber. In this case the condition $z_i = x_i$ is executed. The concentration of the saturated solution is increased up to a condition characterized by the curve S. Cooling of the dephlegmator by the environment is absent.

2 UPORABA INVERZNEGA REKTIFIKATORJA

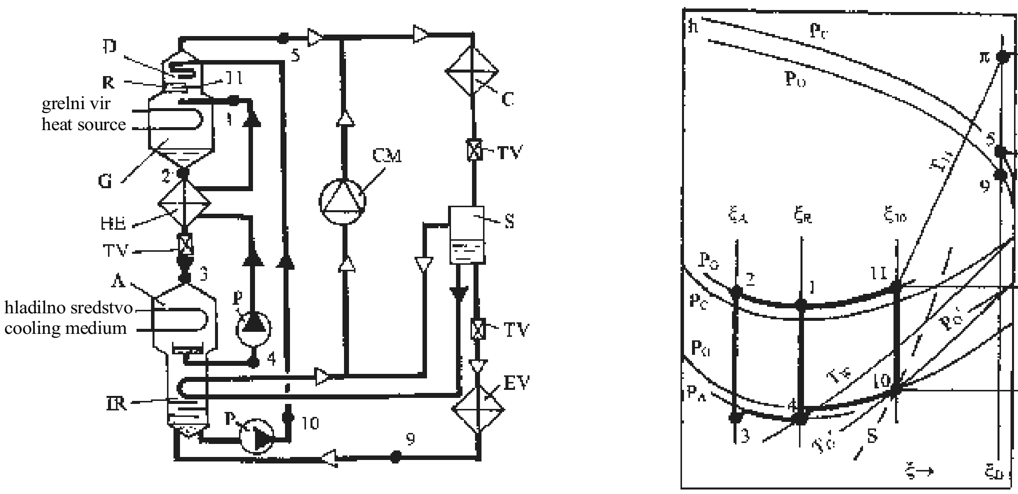
Absorpcijski toplotni pretvornik voda – amoniak z inverznim rektifikatorjem je predstavljen na sliki 3. V tem primeru je celotni tok pare usmerjen iz uparjalnika v inverzni rektifikator. Dodatni proces nasičenja bogate raztopine poteka v inverznem rektifikatorju pri tlaku uparjanja ($p_A \equiv p_{IR} \equiv p_O$).

Stopnja nasičenja bogate raztopine v inverznem rektifikatorju je odvisna od tipa termodinamičnega postopka. Proces nasičenja je lahko adiabatni ali z odvodom toplote, katere količina je odvisna od termofizikalnih lastnosti delovne zmesi. Adiabatni proces v inverznem

2 USE OF AN INVERSE RECTIFICATOR

The absorption water-ammonia thermotransformer with inverse rectificator is presented in Fig.3. The additional saturation process of the strong solution is carried out at the evaporation pressure ($p_A \equiv p_{IR} \equiv p_O$) in the inverse rectificator. The full vapor flow is directed from the evaporator to the inverse rectificator.

The saturation degree of the strong solution in the inverse rectificator depends on the type of thermodynamic process. The saturation process can be adiabatic or with the removal of heat, depending on the thermophysical properties of the working mixture. The adiabatic process in the inverse rectificator



Sl. 3. *Shema in cikel sistema z inverznim rektifikatorjem*
Fig. 3. *Scheme and cycle of the system with inverse rectificator*

rektifikatorju je omejen s cono adiabatne stabilizacije. Nadaljnje nasičenje je v primeru voda - amoniak mogoče samo z odvodom toplote. Tako se lahko pojavi odvod toplote v inverznem rektifikatorju samo pri temperaturah pod temperaturo okolice [4]. Para, ki ni absorbirana v procesu nasičenja, je usmerjena neposredno k osnovnemu absorberju. V tem sistemu ne potrebujemo dveh virov hlajenja. V tej shemi je predvidena stopnja vmesnega dušenja hladiva, ki uporablja del hladilne kapacitete za hlajenje inverznega rektifikatorja. Hladivo, ki se pri tem upari pri p_O', tlačimo nazaj v kondenzator z mehanskim kompresorjem CM (sl. 3).

3 BOLJŠI SISTEM

Boljši sistem (sl. 4) združuje prednosti inverznega rektifikatorja in dodatnega absorberja. Del bogate raztopine, ki se uporablja za hlajenje deflegmatorja, je najprej izpostavljen nasičenju v inverznem rektifikatorju pri tlaku uparjanja (p_O) ter nadalje v dodatnem absorberju, pri srednjem tlaku - $p_{A'}=p_{AA}$.

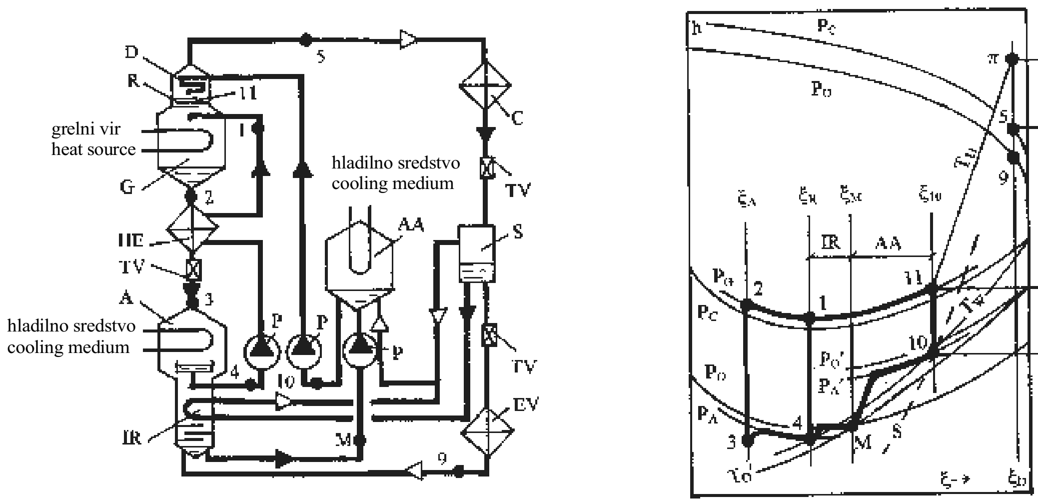
S shemo na sliki 4 je predstavljena toplotna kompresija pare hladiva (nastale v inverznem rektifikatorju hladilnega procesa) v dodatnem absorberju.

is limited to the zone of adiabatic stabilization. Further saturation is possible only in the case of a water-ammonia solution with heat rejection. Thus the heat rejection in the inverse rectificator should occur at temperatures below the temperature of the environment [4]. Vapor not absorbed in the saturation process is directed to the basic absorber. Two cooling sources are missing in this system if we compare it with the previous systems. The refrigerant throttling stage is stipulated in this scheme, i.e. use of a part of the useful cold capacity for cooling of the inverse rectificator. It is necessary to direct to the condenser the refrigerant vapor formed at p_O'. In the scheme (Figure 3) this device is shown as a mechanical compressor.

3 COMPLEX SYSTEM

The complex system (Figure 4) can be created using the advantages of inverse rectificator and additional absorber. The part of the strong solution directed for the cooling of the dephlegmator is exposed to saturation: first in the inverse rectificator at the evaporation pressure (p_O) and then in the additional absorber at intermediate pressure - $p_{A'}=p_{AA}$.

In Figure 4 the thermal compression of the refrigerant vapor (formed in the inverse rectificator cooling process) takes place in the additional absorber.



Sl. 4. *Shema in obtok boljšega sistema*
Fig. 4. *Scheme and cycle of the complex system*

4 PRERAČUN

Karakteristike vseh predloženih shem v tem prispevku so bile računane pri pogoju, da je kapaciteta hlajenja nespremenljiva (Q_O=konst) (sl. 5). Izračun je bil opravljen v širokem temperaturnem razponu uparjanja in kondenzacije, ki je običajen za tovrstne toplotne transformatorje in toplotnega vira T_2=120 do 140 °C. Toplotni pretvornik brez inverznega rektifikatorja in dodatnega absorberja [2] je bil

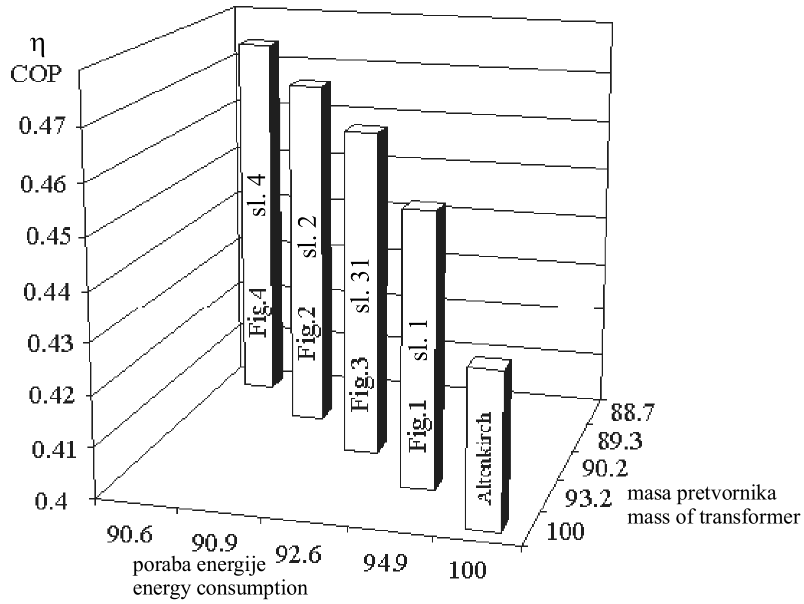
4 CALCULATED CHARACTERISTICS

In this paper the characteristics of all the schemes presented were calculated with the condition of constant cold capacity (Q_O=const). The calculation is carried out over a wide temperature interval of evaporation, and heat source T_2=120 to 140°C. The thermotransformer, without inverse rectificator and additional absorber, presented in the reference [2] was also calculated as a comparison. It was taken izračunan za primerjavo z rezultati sistemov, predstavljenih v tem prispevku, ter vzet kot referenčna vrednost za primerjavo. Za primerjavo porabe energije smo uporabili enake zunanje temperaturne razmere. Rezultati izračunov so predstavljeni v odstotkih, relativno glede na izhodiščni postopek.

Rezultati izračuna (sl. 5) predstavljajo termoekonomsko analizo obravnavanih primerov. Predstavljeni so v tridimenzionalnemu diagram "izkoristek η – masa – poraba energije". Geslo "masa" pomeni celoten investicijski strošek toplotnih pretvornikov, medtem ko geslo "porabljena energija" pomeni obratovalne stroške toplotnih pretvornikov.

as a comparison starting point (at 100%) for the other systems presented in this paper. For the comparison the energy consumption the same external temperature levels were used.

The results are presented in %, relative to the starting point. The results of the calculation (Fig. 5) can be explained as a simple thermoeconomic analysis of the considered cases. They are presented in the three-dimensional diagram: "COP – mass - energy consumption". The term "mass" refers to the "capital costs of the thermotransformer" and the term "energy consumption" is the operational costs of the thermotransformer.



Sl. 5. *Termoekonomska analiza shem na slikah 1 do 4 ter izhodiščne sheme iz literature [2]*
Fig. 5. *Thermoeconomic analysis of schemes in Fig.1 to 4 and scheme from the reference [2]*

Celotna termoekonomska analiza je pokazala, da je mogoče povečati učinkovitost toplotnih pretvornikov z uporabo zapletenih shem. V tem primeru se procesi bolj približajo povračljivim procesom ($\eta_{dejanski}/\eta_{max}$ = 0,6 do 0,7, kjer je $\eta_{max}\approx$0,7 po Stierlinu [7]). Z zapletenostjo sistema se zvečuje število elementov, toda investicijski in obratovalni stroški se znižujejo.

A full thermoeconomic analysis has shown that it is possible to raise the efficiency of the thermotransformer by the use of complex schemes. In this case the processes come nearer to reversible ones (COP_{real}/COP_{max} = 0.6 to 0.7, where $COP_{max}\approx$0.7 by Stierlin [7]). With the increasing complexity of the system the number of elements increases, but the capital and operational costs decrease.

5 SKLEPI

1. Rektifikacijski sistemi z vrnitvijo dela bogate raztopine so bolj gospodarni kakor sistemi brez vračanja.
2. Sistemi z dodatnim nasičenjem dela raztopine so bolj gospodarni kakor sistemi brez nasičenja.
3. S približevanjem koncentracij nasičene raztopine do vrednosti (φ=1) se učinkovitost postopka zvečuje. Potreba po uporabi dodatnega hlajenja deflegmatorja odpade.
4. Sistem z inverznim rektifikatorjem je uporaben ob navzočnosti dveh hladilnih sredstev pri različnih

5 CONCLUSIONS

1. Rectification systems involving the rejection of part of the strong solution are more economic than systems without this rejection.
2. Systems with the additional saturation of part of the solution are more economic than systems without additional saturation.
3. With a finishing concentration of the saturated solution up to a magnitude of (φ=1) the effectiveness of the cycle rises. The necessity for using environmental cooling of the dephlegmator disappears.
4. A system with an inverse rectificator is suitable

temperaturah.
5. Uporaba dodatnega absorberja je ugodna ob navzočnosti samo enega hladilnega sredstva.
6. Zapletenost rešitev povečuje η sistema in razmerja η_{real}/η_{maks}, pri manjših investicijskih in obratovalnih stroških. Uporaba absorpcijskih toplotnih pretvornikov z inverznim rektifikatorjem je upravičena v primeru velikih hladilnih moči naprave.

for two cooling media at different temperatures.
5. The use of the additional absorber is recommended when there is only one medium.
6. The complication of the solutions promotes an increase in the COP of the machine and of COP_{real}/COP_{max}, with the decrease in capital and operational costs. Absorption thermotransformers with an inverse rectificator are best suited to machines with a large cooling capacity.

6 UPORABLJENI SIMBOLI

A - absorber, AA - dodatni absorber, C - kondenzator; CM - kompresor, D - deflegmator, EV - uparjalnik, HE – raztopinski prenosnik toplote, G - generator, IR – inverzni rektifikator; P - črpalka, R - rektifikator, S - separator, TV – dušilni ventil.

6 NOMENCLATURE

A - absorber, AA - additional absorber, C - condenser, CM - compressor, D - dephlegmator, EV - evaporator, HE – solution heat exchanger, G - generator, IR - inverse rectificator, P - pump; R - rectificator, S - separator, TV - throttle valve.

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