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Review scientific paper

Absorpcijske naprave za pridobivanje hladu in toplote
Absorption Refrigerating and Heating Machines

BRANKO GAŠPERŠIČ

Na Fakulteti za strojništvo v Ljubljani smo razvili novo generacijo absorpcijskih toplotnih črpalk, to je večnamenski absorpcijski toplotni transformator. Naprava lahko hkrati pridobiva hlad in toploto, npr. za klimatizacijo zraka. Porablja zelo majhne količine električne energije, ker je za samo obratovanje potrebna le toplotna energija temperatur, višjih od 85°C. Z izvedenimi absorpcijskimi toplotnimi napravami lahko dvignemo temperaturno raven odpadni toploti tudi za 50K. Nadaljnji pomembni vidik je, da absorpcijske naprave ne vsebujejo nobenih halogeniziranih ogljikovodikov, ampak obratujejo z zmesjo vode in litijevega bromida. S tema snovema delamo preprosto, ker nista strupeni in ne gorljivi ter ne razvijata nobenih plinov, ki bi bili škodljivi za ozračje.

Ključne besede: naprave toplotne absorpcijske, gretje, hlajenje, toplota odpadna

At the Faculty of Mechanical Engineering in Ljubljana a new generation of absorption heating pumps i.e. absorption heat transformers for general purpose has been developed. By these devices cold and heat are produced simultaneously to serve, for example, the purpose of air-conditioning. A very low quantity of electric power is used, since the operation itself takes up the heat energy of temperatures higher than 85°C. By realisation of the absorption heat devices mentioned the temperature level of waste heat could also be raised by 50 K. A further aspect of importance is also the fact that these absorption devices do not contain any halogented hydrocarbons, they operate on the basis of a mixture of water and lithium bromide. It is very convenient to operate with these substances as they are neither poisonous nor inflammable. They also do not develop any *gases which would cause pollution.*

Keywords: absorption heating device, heating, cooling, waste heats

0 UVOD

Sedanje cene energije so nizke in velika verjetnost je, da industrijsko preudarno izkoriščanje toplotne energije v bližnji prihodnosti lahko pri pomenu samo pridobi. Cene se bodo ponovno povečale in tudi politični ukrepi glede okolja zahtevajo zmanjšanje oddaje toplote in škodljivih snovi v okolico. Pomembno je še, da z razumno uporabo toplote ne pride do povečane porabe električne energije. Porabo primarne energije je mogoče zmanjšati samo, če ponovno pridobljeno toploto neposredno vodimo v proces. Pri tem moramo temperaturo odpadni toploti dvigniti, kar lahko izvedemo s krožnimi procesi, ki porabljajo eksergijo ali toplotno energijo, sestavljeno iz eksergije in anergije [1]. Tako je večnamenski absorpcijski toplotni transformator (VATT) naprava, ki je primerna za industrijsko uporabo odpadnih toplot [2].

Vse več je zanimanja za absorpcijske hladilne naprave (AHN), ki so gnane s toplotno energijo. V poletnih mesecih je te dovolj na voljo in takrat obstajajo povečane potrebe po ohlajeni vodi za klimatizacijo zraka in za odvod toplote iz industrijskih procesov. Torej toplota dela hlad, ta zamisel je stara, sedaj pa stopa v polno veljavo.

0 INTRODUCTION

The present prices for energy are rather low but it is not difficult to foresee that the rational exploitation of the heat energy can only gain in importance in the nearer future. The prices will be raised again, nevertheless the politics will take some measures relevant to our environment, such as the reduction of heat loss and the diminishing of polluting substances. It is important that the rational exploitation does not increase the demand on electric energy. The consumption of the primary energy could be diminished only in cases, when the recovered heat is directly returned to the process again. Hereby the waste heat temperature must be raised. This occurs by means of the circular processes using exergy or heat energy consisting of exergy and anergy [1] for compressor drive. The absorption heat transformer for general purposes (VATT) is such a device, which is very convenient for industrial exploitation of waste heats [2].

The absorption cooling devices (AHN) driven by heat energy are arousing greater interest than ever. The summer months offer this energy sufficiently, not to mention the increased requirements of cooled water for either air conditioning or water outlet from the industrial processes. The fact that the cold is produced by

Uspešni so objekti, pri katerih je bila izvedena temeljita gospodarsko-energijska analiza že v času priprave. Podjetja, ki oskrbujejo porabnike z daljinskim toplovodnim ogrevanjem, so še kako zainteresirana, da bi dobavo toplotne energije časovno podaljšali in s tem prišli do bolj gospodarnega ravnanja. To še posebej velja za poletne mesece, ko porabljamo ogrevanje samo za toplo sanitarno vodo, tako da je obremenitev toplarne glede na proizvodne zmogljivosti komaj okrog 15 odstotkov. Zato se dobavitelji tople vode trudijo, da bi pridobili nova področja porabe.

1 SPLOŠNO TRŽNO POVPRAŠEVANJE PO ABSORPCIJSKI HLADILNI TEHNIKI

Število absorpcijskih toplotnih naprav (ATN) se iz leta v leto povečuje, tako so bile ZDA do leta 1970 na prvem mestu po številu vgrajenih ATN, potem jih je prehitela Japonska [3]. Prav ti dve državi bosta v naslednjih letih najbrž prevladovali v proizvodnji. Večje število teh naprav bo v Evropi, deželah v razvoju južne Azije, srednje in južne Amerike ter Afrike - deželah, ki sodijo k trgom z največjo rastjo.

Glavni razlog za povečano prodajo v nerazvitih državah je v tem, da so ATN v primerjavi z drugimi napravami stroškovno zelo ugodne. Tako so stroški plinsko gnane AHN in pripadajoče omrežje znatno nižji od stroškov električno gnane hladilne naprave s pripadajočo elektrarno in električnim omrežjem.

Obstajajo pa tudi določene ovire za absorpcijsko hladilno tehniko in druge načine plinskega hlajenja, to so:

- nezadostna infrastruktura na področjih prodaje (kadrovske težave),
- konstrukterji in obratovalni delavci se na tehniko ne zanesejo,
- omejena razpoložljivost in visoki stroški za majhne naprave.

Gospodarnost uporabe zemeljskega plina in še posebej gretja z vodo iz toplarn sta namenjeni za premagovanje omenjenih ovir. Dosegljive so mnogo obetajoče, svetovno razširjene tehnike:

- nadaljnje raziskave, razvoj in demonstracije za znižanje stroškov izdelave in optimizacijo moči,
- finančne spodbude preskrbovalnih podjetij z energijami za nadomestilo visokih načrtovanih stroškov,
- podpiranje razvoja infrastrukture za področje prodaje,
- razvoj daljinskega ogrevanja in naprav ter hladilnih sistemov,

the heat is not new, yet it has lately gained much attention. There are successful projects, in which the economical energy analysis has been thoroughly made as early as in the preparation course. Also the suppliers in the district heating system are very interested in the supply of heat energy for a longer term in order to gain more economical profit. This concerns the question of summer months, when the heating system is used for hygienic water only. The heating plant exploitation acccording to its production capacity, amounts in this case to about 15% only. For this reason the hot water suppliers are trying to gain new consumption fields.

1 GENERAL MARKET INTEREST IN THE ABSORPTION REFRIGERATING SYSTEM

The number of sold absorption heat devices (ATN) continues to grow from year to year continously. The USA held first place in the number of ATN installed up till 1970, after that Japan overtook the leadership [3]. Most probably these two countries will still dominate in production in the following years. A greater number of ATN will be installed in Europe, in the developing countries of South Asia, Central and South America, and Africa, i.e. countries belonging to markets with the most intensive growth.

The main reason for this growing sale of ATN in the developing countries is to be found in lower production costs in comparison to the other devices. The costs for a gas driven AHN and belonging network is considerable lower than the costs for an electrical rerigerating device with belonging power plant and electric network.

There are also some obstacles to the absorption refrigerating technique and other ways of gas refrigerating, such as:

- insufficient infrastructure in the sales region (staff problems),
- design engineers and workers do not rely on the technique,
- limited availability and high costs for small equipment.

The economical aspect of the exploitation of natural gas, and especially of water heating by thermal plants, is directed to surmounting the obstacles mentioned above. There are many promising, worldwide techniques to achieve :

- advances in research, development and demonstrations, with a view to reducing the production costs and to increasing power optimisation,
- financial stimulation by energy suppliers for compensation of high projected costs,
- support fori infrastructure development in the sales region,
- development of district heating and of its equipment, and also the development of refrigerating systems,

– podpora hibridnim napravam (plinska in električna energija), da bi povečali prilagodljivost in optimizacijo naprav.

Zaradi zanimanja za majhne absorpcijske naprave, ki imajo poleg hladilne moči okrog 10 kW še toplotno grelno moč, npr. naprava VATT [2], so v pospešenem razvoju. Tako dandanes dosegajo toplotna razmerja na strani hlajenja vrednosti večje od 0,9, na strani gretja pa večje od 1,8.

2 POVEZAVA DALJINSKEGA OGREVANJA S SISTEMI ATN

Najbolj učinkoviti in gospodarni sistemi so tisti, ki združijo proizvodnjo električne in toplotne energije. Učinkovitost AHN ocenjujemo s toplotnim razmerjem $\xi = \dot{Q}_R / \dot{Q}_G$ med hladilno močjo in dovedenim grelnim toplotnim tokom. Grelne izgube lahko izražamo s kalorično določenim grelnim učinkom toplovodnega omrežja η_K in številom pretvorbe v električno energijo σ. To je razmerje med pridobljeno električno energijo pri združenem procesu in primarno z gorivom dovedeno grelno toploto.

Če je proizvodnja hladu ločena, torej ko je AHN povezana neposredno s parnim ali toplovodnim kotlom, potem mora biti električna energija pridobljena v nadomestni termoelektrarni. V tem primeru je potrebna količina goriva dana z:

$$m_B = Q_{B,G} / Q_G = \left[\frac{1}{\eta_K} + \frac{\sigma}{\eta_M \eta_{KW}} \right] \Big/ \xi$$

kjer sta η_K izkoristek nadomestnega kotla in η_{KW} izkoristek bilančno priključene termoelektrarne. Pri predpostavljenih vrednostih za ξ = 0,63 do 0,67, η_K=0,9 in η_{KW}=0,38 dobimo relativne prihranke goriva pri povezavi sistema za preskrbo s toploto z združitvijo električne ter toplotne energije in z AHN. Ti prihranki goriva so okrog 30% in tudi za običajne toplarne s parnimi turbinami (σ= 0,2 do 0,3) je prihranek dejansko okrog 10%. Poleg tega se zmanjšuje še vpliv na okolico. Emisijo CO_2 pri uporabi zemeljskega plina in omenjenih sklopih je mogoče zmanjšati za okrog 50 odstotkov.

Najnižja temperatura vode iz daljinskega ogrevanja v poletnih mesecih naj ne bi bila pod 100°C, ker vpliva na samo konstrukcijo ATN ali VATT. Prednost obeh naprav je še v dolgi dobi trajanja, ker je le malo mehanskih in s tem obrabnih delov v uporabi. Dodatna prednost je v odličnem obnašanju naprav pri delnih obreme-

– supporting hybrid systems (gas and electric power) in order to increase flexibility and optimisation of the equipment.

Due to the growing interest in small absorption devices that offer, in addition to cooling power of about 10 kW, also heating power - as for example the device VATT [2] - the intensive development of these devices is in course. Presently these devices achieve heat ratio values greater than 0.9 on the cooling side and greater than 1.8 on the heating side.

2 DISTRICT HEATING IN CONJUNCTION WITH ATN SYSTEMS

The most effective and economical systems are those which perform the production conjunction of electric and heating energy. The efficiency of AHN is defined by the heat ratio $\xi = \dot{Q}_R / \dot{Q}_G$ between the cooling power and the heating current supplied. Heat losses may be described by the calorically defined heating efficiency of the heating network η_K and the number of transformations in the electric energy σ. This is the ratio between the electric energy produced in the connected process, primarily by means of fuel obtained heat.

If the production of cold is separated, i.e. AHN is connected directly to the steam or heating boiler, then the electric energy must be produced by a substitute generating plant. In this case, the necessary fuel quantity is given by:

η_K is the efficiency of the substitute boiler and η_{KW} is the efficiency of the balance connected generating plant. On the assumption of the values for ξ = 0.63 to 0.67, η_K = 0.9 and η_{KW} = 0.38, the relative savings on the fuel in the connected heating system are obtained, if there is a connection between the electric and heat energy, and also with AHN. These savings on the fuel are about 30%, whereas the conventional heating plants with steam turbines (σ = 0.2 up to 0.3) find the real saving also about 10%. Beside this, the influence on the environment is hereby also reduced. The emission of CO_2 when natural gas and the connections mentioned are used, may be decreased by about 50%.

The lowest water temperature in the district heating might not be below 100°C, and this exerts an influence upon the structure of ATN or VATT itself. Priority is given to both devices acording to their long-life term, since there are only small numbers of mechanical, and hereby wasting, parts in use. Additionally, the operation of the devices is superior if they are only partly

nitvah. Te se brezstopenjsko prilagajajo proizvodnji hladu ali toplote v področju od 10 do 100% brez omembe vrednih izgub pri učinku.

3 IZHODIŠČA ZA NAČRTOVANJE IN GOSPODARNOST

Ker so stroški glede na hladilno moč pri AHN v primerjavi s kompresorsko gnano hladilno napravo še posebej pri majhnih hladilnih močeh med 200 in 700 kW nekajkrat višji, je treba pri načrtovanju takšnih naprav v novo ali že razpoložljivo gradbeno tehniko dati še poseben pomen [4]. Učinkovitost AHN je odvisna od količine porabljene toplotne energije na pridobljeno količino hladu, predvsem je pa odvisna še od vstopnih temperatur grelne in hladilne vode. Z zvečano velikostjo AHN se zmanjšujejo investicijski stroški na enoto hladilne moči. Pred uresničitvijo naprave izvedemo raziskavo o gospodarnosti.

Od leta 1994 obratuje AHN z močjo 246 kW v bolnišnici z okrog 450 ležišči, kar pomeni osnovno hladilno obremenitev [4]. Za pokrivanje konic je namenjena kompresorska hladilna naprava z močjo $\dot{Q}_R$ = 350 kW. V klimatizacijske namene se voda ohlaja od 12°C na 8°C in za odvajanje toplote iz absorberja in kondenzatorja skupne moči 577 kW uporabljajo hladilno vodo s temperaturami 26°C do 32°C. Toplotno moč $\dot{Q}_G$ = 346 kW dovajajo generatorju AHN, to je voda iz toplovodne mreže temperatur 90°C do 70°C. Specifični stroški, ki vključujejo vse dodatke, dobavo, montažo in zagon, so bili neto 750 DEM/kW hladu.

V drugem primeru je bila uporabljena AHN z močjo $\dot{Q}_R$ = 1400 kW pri klimatizaciji bančne stavbe za ohlajanje vode od 12°C na 6°C. Celotna potrebna moč grelne toplote je 2080 kW, pri tem se toplarniška voda ohladi od 100°C na 79,5°C. Specifični stroški, ki vključujejo še dobavo, montažo in zagon, so bili v neto znesku 993 DEM/kW hladu.

4 ATN, KI DELAJO Z ZMESJO VODE IN LITIJEVEGA BROMIDA

Za hladilno sredstvo uporabljajo vodo, za absorpcijsko sredstvo pa litijev bromid. Danes je velika prednost ATN in VATT v tem, da za delovna sredstva uporabljajo naravne snovi. V prid uporabi ATN je tudi možnost izrabe odpadnih toplot, toplote vode iz daljinskega ogrevanja in sončne energije. Neposredno jih lahko kurijo z zemeljskim ali drugim plinastim gorivom. Kompresor hladilne naprave pa ženejo s plinskim motorjem. Gretje s toplotnimi črpalkami je zanimivo, večinoma uporabljajo električno gnane, zanemarjajo pa prednosti absorpcijske tehnike.

loaded. They are stagelessly adapted to the cold and heat production in the range of 10 up to 100% without any valuable efficiency losses.

3 STARTING-POINTS FOR PLANNING AND ECONOMY

Since the costs relating to the cooling power of AHN compared with the compressor driven cooling device - especially at small cooling powers between 200 and 700 kW - are several times higher, it is necessary to give special attention to the planning of such devices in either new or already available construction [4]. The efficiency of AHN depends on the quantity of heat energy used on the cold quantity produced, but first of all, the efficiency still depends on the inlet temperatures of heating and cooling water. By increasing the size of AHN the investment costs are reduced as regards the cooling power unit. Before developing the equipment, first the research in the economy needs to be worked out.

Since 1994, the AHN device of the power of 246 kW has been operating in a hospital with 450 beds that is the basic calling load [4]. To cover the peaks, a compressor cooling device of the power of $\dot{Q}_R$ = 350 kW is used. For the air-conditioning the water is cooled from 12°C to 8°C, and for heat pumping from the absorber and condenser with total power of 577 kW, the cooling water with temperatures from 26°C to 32° C is used. The heat power $\dot{Q}_G$ = 346 kW is delivered to the AHN generator. This is the water from the heating network with temperatures of 90°C to 70°C. Specific costs including all extras, delivery, mounting and starting amounted to net 750 DEM/ kW cold.

As the second example, AHN of the power $\dot{Q}_R$ = 1400 kW was applied in the air-conditioning of the bank building for the water cooling from 12°C to 6°C. The total required power of heating is 2080 kW, where the water from the heating plant cools from 100°C to 79.5°C. Specific costs including delivery, mounting and starting amounted to net 993 DEM/kW cold.

4 ATN WORKING WITH THE WATER LITHIUM BROMIDE MIXTURE

For the refrigerant the water is used, and for the absorbtion medium the lithium bromide. The great advantage of ATN and VATT to is that they use substances as natural working media. In the application of ATN, the advantage also lies in the possibility of using all waste heats, water heats from district heating and solar energy. They may also be heated by natural gas and other gas fuels. The compressor of the cooling device is driven by a gas motor. The heating by heat pumps is also of great interest. These pums are mostly electrically driven, whereas the advantages of the

Na katedri za toplotno in procesno tehniko se že več let ukvarjamo z razvojem ATN in VATT [2], [5] in [6]. Teoretična dela obsegajo analitične ali računalniško podprte izračune krožnih procesov za ATN, prek termodinamičnih analiz do ekonomskih izračunov. Poleg tega potekajo še primerjalne raziskave rabe energije. V okviru eksperimentalnih del smo zgradili naprave za merjenje lastnosti snovi ter toplotnih in snovskih prestopnosti.

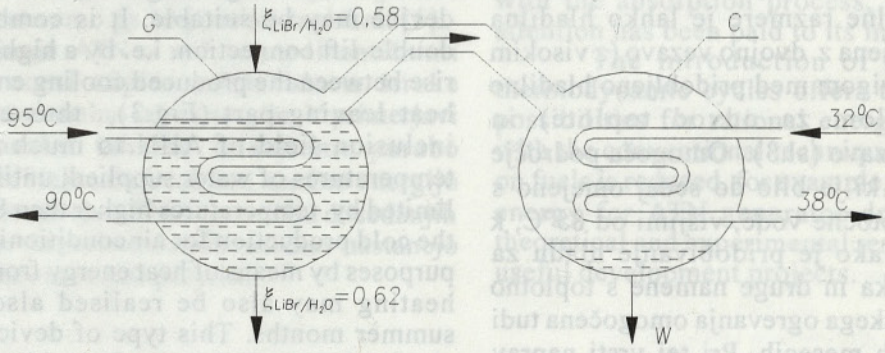
Absorpcijski proces temelji na tem, da ima raztopina vode in litijevega bromida veliko zmožnost sprejemanja vodne pare iz uparjalnika. Če vodna para s temperaturo T pride v stik z bogato raztopino litijevega bromida (do okrog 62%), absorbira raztopina paro in se pri tem segreje na temperaturo $T+\Delta T$, kar je odvisno od koncentracije. Absorpcijsko toploto, ki se pri tem sprošča, odvajamo v okolico ali jo koristno uporabimo. Pri absorpciji postaja raztopina redkejša in se potem v drugem delu naprave ponovno koncentrira.

Toplotno razmerje povračljivega krožnega procesa ostane nespremenjeno, dejansko pa se spreminja samo zaradi nepovračljivosti. Za dvojico snovi voda - litijev bromid pri enostopenjski ATN leži dejanski ξ med 0,7 in 0,8 (sl. 1), za amoniak z vodo pa je $0,4 < \xi < 0,6$. Na tržišču je znana tudi dvostopenjska ATN (sl. 2) in doseže z vodo in litijevim bromidom toplotno razmerje okrog 1,2.

At the Chair of Heat and Process Engineering we have been dealing with ATN and VATT [2], [5] and [6] for some years. Our theoretical works comprise analytic calculations and computer software cycles for ATN from thermodynamic analyses up to economic calculations. In addition to these, also comparative researches of energy consumption are also still in course. Within the scope of the experimental works, devices for measurement of substance characteristics as also for measurement of heat and mass transfer coefficients have been built.

The basis of the absorption process illustrates the fact that the solution of water and lithium bromide is highly capable of absorbing the water vapour from the evaporator. If water vapour with a temperature T comes in contact with the solution of lithium bromide (up to about 62%), the vapour is absorbed by the solution and warmed up to the temperature $T + \Delta T$, depending upon the concentration. The resulting absorption heat is either carried away in to the surroundings or is used up advantageously. By the absorption, the solution becomes weaker, but in the second part of the device it again becomes concentrated.

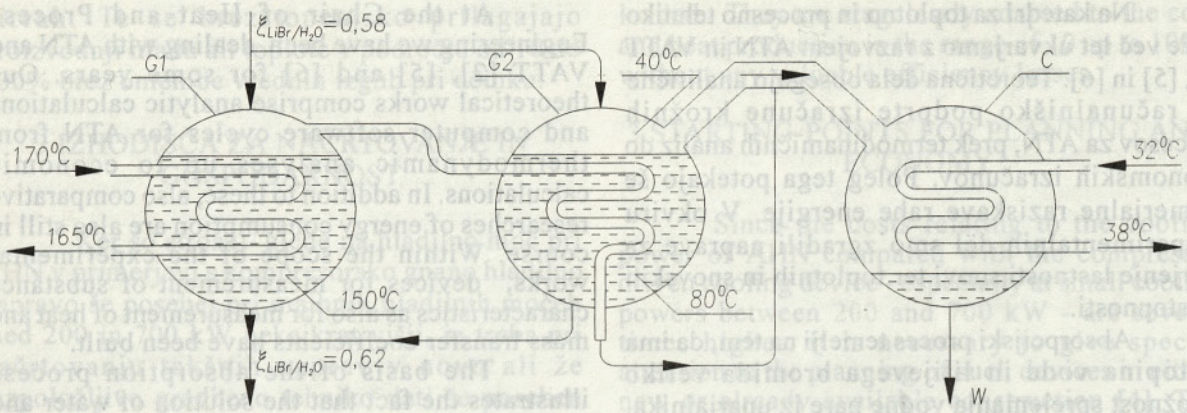
The heat ratio of the reversible cycles remains unchanged; in fact it only changes due to the irreversibility. For the couple of water/lithium bromide with single-effect ATN the real ξ is between 0.7 and 0.8 (Fig.1), but for ammonia/water it is $0.4 < \xi < 0.6$. On the market there is also a double-effect ATN (Fig.2). With the water/lithium bromide solution it reaches a heat ratio of about 1.2.



A - absorber,
C - kondenzator,
E - uparjalnik,
G - generator,
CW - hladilna voda,
W - ohlajena voda,
V - para

A - absorber,
C - condenser,
E - evaporator,
G - generator or boiler,
CW - cooling water,
W - cooled water,
V - vapour

Sl. 1. *Enostopenjski generator*
Fig. 1. *Single-stage generator*



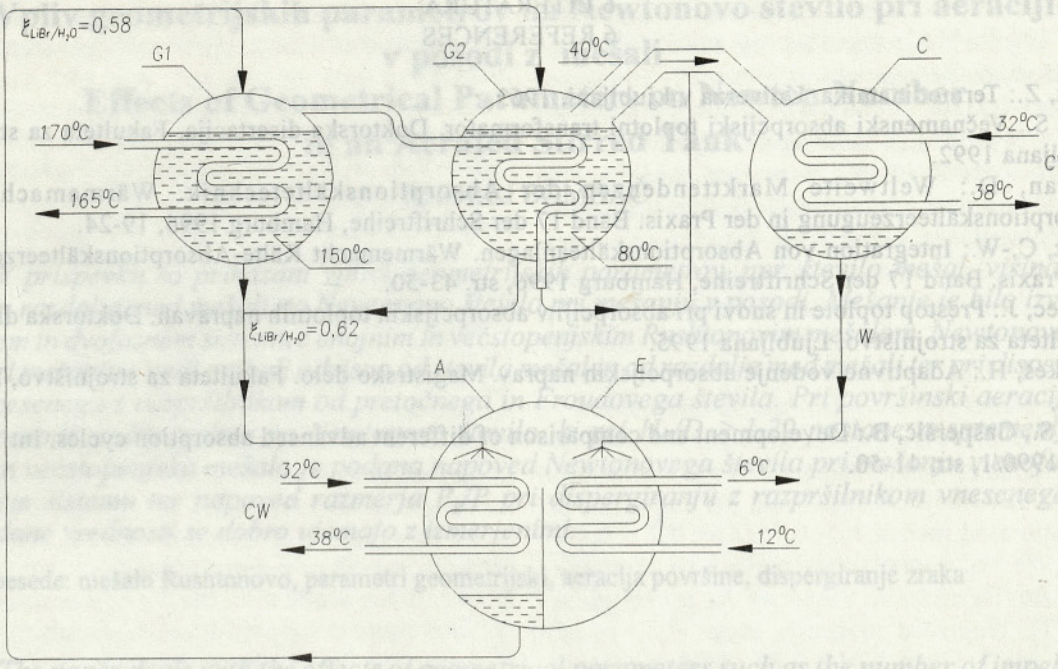
Sl. 2. *Dvostopenjski generator*
Fig. 2. *Double-stage generator*

Omenjena toplotna števila so manjša od tistih, ki jih dosežejo kompresorski hladilni stroji. Za večstopenjske ATN velja, da so zapletene in drage. Da bi ugotovili prednosti večstopenjskih procesov hitro in razumljivo, moramo prikazati njihove pomembne lastnosti. Prvi korak za to je klasifikacija in sistematizacija večstopenjskih krožnih procesov [7]. Potem lahko večstopenjske ATN razdelimo v znane enostopenjske kompresorske in AHN ter jih označimo kot elementarne krožne procese. Toplotna razmerja in tehnične lastnosti večstopenjske AHN lahko zelo hitro določamo iz ustreznih razmerij za enostopenjske elementarne krožne procese po metodi superponiranja.

Primerna za vključitev v značilne daljinske ogrevalne razmere je lahko hladilna naprava, ki je spojena z dvojno vezavo (z visokim temperaturnim dvigom med pridobljeno hladilno energijo in delom za odvod toplote) in enostopenjsko vezavo (sl.3). Omogoča področje vključitve AHN, ki je bilo do sedaj omejeno s temperaturami dotočne vode, višjimi od 85°C, k znatno nižjim. Tako je pridobivanje hladu za klimatizacijo zraka in druge namene s toplotno energijo iz daljinskega ogrevanja omogočena tudi v tipično poletnih mesecih. Pri tej vrsti naprav bodo stroški pridobivanja hladu približno enaki stroškom, ki jih dosežemo s kompresorskimi napravami oziroma z AHN, ki obratujejo pri višjih temperaturah dovodne vode iz daljinskega omrežja. AHN pridobiva hlad v uparjevalniku, v absorberju pa raztopina absorbira vodno paro. Raztopino obnovimo v dvostopenjskem generatorju, kakor je razvidno s slike 3.

The heat ratia mentioned above are smaller than those reached by compressor refrigerating machines. The multi-stage ATNs are known to be very complicated and expensive. To find the advantages of these processes as quickly as possible, their important characteristics must be shown. The first step is the classification and systematization of multi-stage cycles [7]. After that the multi-stage ATNs may be divided into known single-stage compressor ATNs and AHNs with the indication of elementary cycles. The heat ratios and technical characteristics of multi-stage AHNs may be rapidly defined from the corresponding ratios for single-stage elementary cycles according to the method of superposition.

For inclusion in the typical district heating conditions, the single-stage/double-lift refrigerating device may be suitable. It is combined with a double-lift connection, i.e. by a high temperature rise between the produced cooling energy and the heat leaving part (Fig.3), thus enabling the inclusion field of AHN to much more lower temperatures of water supplied; until now it was limited by temperatures higher than 85°C. Hence, the cold production for air conditioning and other purposes by means of heat energy from the district heating may also be realised also in typical summer months. This type of device will show almost the same cost rate for cold production as is the case with the compressor device or AHN, respectively, which work at higher temperatures of supplying water from the district heating. The double-stage AHN produces cold in the evaporator, while in the absorber the water vapour is absorbed by the solution. The solution is regenerated in the double-stage generator as shown in Figure 3.



Sl. 3. *Dvostopenjska absorpcijska hladilna naprava*
Fig. 3. *Double-stage absorption cooling device*

5 SKLEP

ATN sestoji iz štirih glavnih komponent, v katerih poteka toplotna ali toplotno-snovna izmenjava. Poglavitni stroški so povzročeni prav z vgrajenimi prenosnimi površinami. Za kondenzacijo in uparjanje imamo dobra izhodišča glede analitičnih nastavkov in tudi rezultatov meritev. To v mnogo manjši meri velja za proces absorpcije, zato smo ga še posebej raziskali [5].

Uvajanje ATN z več termodinamičnimi krožnimi procesi odpira načrtovalcem široke možnosti za racionalno rabo energije. V primerjavi s konvencionalno tehniko zmanjšamo porabo goriv, npr. tudi tako, da izrabimo sončno energijo za pogon generatorja ATN. Na temelju dosedanjih teoretičnih in eksperimentalnih raziskav nastanejo lahko uporabni razvojni projekti.

5 CONCLUSION

ATN is divided into four main components, where the heat or heat-mass exchange takes place. The main costs are involved by the design of transfer surfaces. With regard to condensation and evaporation, we have good starting points in the analytical grounds and results of measurements. However, this is not the case with the absorption process, therefore special attention has been paid to its investigation [5].

The introduction of ATN with many thermodynamic cycles offers the planners great possibilities for rational energy use. Compared with the conventional technique, the requirement on fuels is reduced, for example, by using the solar energy for ATN generator drive. The present theoretical and experimental research may lead to useful development projects.

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6 REFERENCES

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