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Sistemi toplotnih premikov v procesih s plinskimi turbinami
Heat Shifting Systems in Gas Turbine Cycles

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S povečano industrializacijo in sočasno elektrifikacijo se je tudi poraba fosilnih goriv v tem stoletju nenehno zvečevala. Kurjenje teh goriv je v zadnjih stotih letih povečalo delež CO_2 v ozračju za okrog 25 odstotkov. Pojem učinka tople grede je s tem postal izredno pereč. Industrijske države morajo, ker so najbolj odgovorne za posledice učinka tople grede, emisije CO_2 krepko zmanjšati, če naj se človeštvo izogne klimatski katastrofi.

Pri zvečevanju potrebe po električni energiji, ki se napoveduje za naslednja leta, je mogoče doseči potrebno zmanjšanje emisij CO_2 samo z doslednim varčevanjem z energijo in z izdatnim povečanjem izkoristka, tako pri vseh porabnikih kakor tudi v termoelektrarnah.

Sodobni kombinirani plinski in parni procesi pomagajo povečati izkoristek, povezava proizvodnje električne energije in toplote pa omogoča potrebno veliko izrabo goriva.

Za uvajanje povezane proizvodnje električne energije in toplote je treba razviti nove tehnologije. Majhna potreba po toploti poleti zahteva pri obratovanju, usmerjenem v proizvodnjo toplote, negospodarno obratovanje postroja pri delnih obremenitvah, pri obratovanju, usmerjenem v proizvodnjo električne energije, pa spuščanje odvečne toplote v ozračje.

Sistemi toplotnih premikov omogočajo s preprostim krožnim procesom plinske turbine veliko neodvisnost obratovanja v širokem območju pokrivanja potreb po električni energiji in toploti. S sodobnimi prenosniki toplote postaja pri tem staro načelo regeneracije zopet pomembno. Pri spremenljivem vključevanju prenosnika toplote je mogoče iz razpoložljivega goriva pridobiti, pač glede na potrebe, ali več toplote ali več elektrike. Pri ustrezni zasnovi je mogoče doseči, da se izkoristek poveča tudi za 25 odstotkov.

With an increasing degree of industrialisation and simultaneous electrification, fossil fuel consumption has increased constantly this century. Over the last hundred years the combustion of fossil fuels has caused an increase in the amount of CO_2 in the atmosphere of about 25%, making the greenhouse effect a critical issue. In order for the world to avoid a climatic catastrophe, industrial countries, being the most responsible for the greenhouse effect, will have to drastically reduce CO_2 emissions.

With the increasing need for electrical power predicted for the coming years it will be possible to achieve the required reduction of CO_2 emissions only through consistent conservation of energy and a considerable increase in the efficiency of all consuming devices as well as thermal power plants.

Modern combined gas and steam cycles enable increased efficiency, while the cogeneration of electrical power and heat enables the required high fuel conversion rate.

New technologies will have to be developed for the cogeneration of electrical energy and heat. In operation oriented towards the production of heat, low demand for heat in summer will cause non-economical operation of the plant at partial loads, while operation directed towards the production of electrical power will require the release of waste heat into the atmosphere.

Using a simple cycle gas turbine, heat shifting systems provide great independence of operation over a wide range of demands for electricity and heat. With modern heat exchangers, the old principle of regeneration is again becoming interesting. With a variable operation of a heat exchanger, it will be possible to produce more heat or more electricity from consumed fuel, depending on demand. With an appropriate design, it will be possible to achieve an increase in efficiency of up to 25%.

0 UVOD

Sodobni kombinirani plinski in parni turbinski procesi omogočajo energetskemu gospodarstvu zagotavljati električno energijo z velikimi izkoristiki in obenem intenzivno varovati okolje. Če pridobivamo iz teh postrojev še toploto, lahko dosežemo celo skoraj 90-odstotno izrabo goriva, s čimer varujemo tako zaloge fosilnih goriv kakor tudi okolje.

0 INTRODUCTION

Modern combined gas turbine and steam turbine cycles enable the highly efficient production of electrical power and, simultaneously, intensive environmental protection. If, in addition, heat is produced at such plants, a fuel conversion rate of almost 90% can be achieved, which means additional preservation of fuel reserves and environmental protection.

Pri povezavi pridobivanja električne energije in toplote prihaja v nekaterih primerih do težav. Tako na primer poleti ne vemo, kam s sproščeno toploto, medtem ko je potrebna vsa električna energija. Pozimi pa so razmere takšne, da je potrebne kar največ toplote, čeprav je električne energije dovolj.

Seveda lahko dela poleti plinska turbina z vso močjo, pri čemer daje njen sistem za odpadno toploto največjo mogočo količino pare, ki jo oddaja parni turbini, preostanek toplote pa, kakor pri običajnem kombiniranem procesu, spušča v okolje (obratovanje, usmerjeno v pridobivanje električne energije). Pozimi je mogoče z dodatnim kurjenjem v sistemu odpadne toplote dobivati več toplote, in obratovati s turbino z delno močjo, da bi pridobili samo toliko električne energije, kolikor jo omrežje trenutno potrebuje (obratovanje, usmerjeno v pridobivanje toplote). Velika stopnja izrabe goriva pri tem ni več dosegljiva.

Potrebujemo torej sisteme, ki bi omogočali plinskemu turbinskemu postroju (s parno turbino ali brez nje), da daje po potrebi več električne energije ali več toplote, pri tem pa ohranja velik izkoristek: to so sistemi toplotnih premikov.

Ena izmed možnosti za rešitev tega problema so plinske turbine, ki delujejo z regeneracijo.

1 REGENERACIJA

Zadnje čase obratujejo le redke plinske turbine v krožnem procesu z regeneracijo. Razlogi za to so po eni strani hiter razvoj plinskih turbin v zadnjem času in s tem doseženo povečanje izkoristka v navadnem procesu, po drugi strani pa težave, ki jih lahko povzroča obratovanje turbine z običajnim regeneratorjem.

Plinske turbine gradijo dandanes s tlačnimi razmerji, ki so v bližini optimuma glede specifične moči ali v bližini optimuma glede izkoristka [1], [2]. Optimumi so pri tem močno odvisni od vstopne temperature v turbino. Če je temperatura višja, je pri tem potrebno tudi večje tlačno razmerje. Pri takšnih tlačnih razmerjih prinaša uvedba regeneracije le majhno izboljšanje izkoristka, če sploh kakšno. Od nekega tlačnega razmerja navzgor pa regeneracija sploh ni več mogoča, ker je temperatura za kompresorjem višja od temperature plinov po njihovi ekspanziji v turbini (sl. 1 do 3).

Slika 4 prikazuje, koliko je izkoristek postroja lahko boljši, če naprava obratuje v regenerativnem procesu.

Po tej sliki je pri plinski turbini z nizkim tlačnim razmerjem mogoče močno izboljšati izkoristek postroja že samo z dodatkom regeneracije. Še bolj je mogoče izboljšati izkoristek z

In some cases, problems occur during cogeneration of electrical power and heat. In summer, for example, these is no use for released heat, while full production of electrical power is necessary. In winter, however as much heat as possible has to be produced, while there is eventually enough electrical power available.

Naturally, a gas turbine can operate at full power in summer, whereby its waste heat system produces the maximum possible amount of steam for expansion in the steam turbine, while the remaining heat, as happens in a usual combined process, is released into the environment (operation directed towards the production of electric power). In winter it is possible to acquire more heat with additional firing in the waste heat system and operate the turbine at partial load in order to produce only as much electric power as needed in the net at that time (operation directed towards the production of heat). A high degree of fuel conversion rate, however, cannot be achieved in this operation.

Systems are therefore required which would enable gas turbine plants (with or without a steam turbine) to produce more electric power or more heat, according to requirements, and at the same time retain a high fuel conversion rate: such systems are called heat shifting systems.

One of the possibilities for solving this problem are gas turbines which use the principle of regeneration.

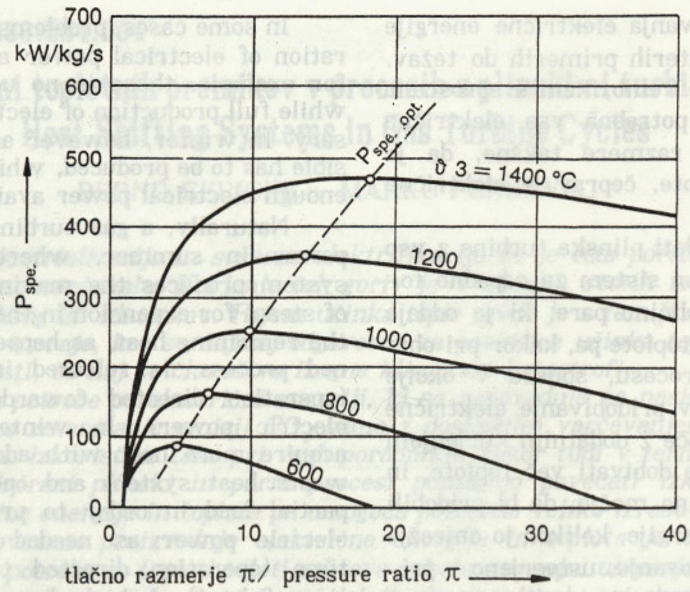
1 REGENERATION

Not many gas turbines have been installed based on regeneration during recent years. The reasons for this are on one hand the considerable development of gas turbines and a subsequent increase in the efficiency of the simple cycle, and on the other hand difficulties which can be caused by the operation of a gas turbine with a classical regenerator.

Nowadays gas turbines are designed with pressure ratios either near the optimum with regard to specific power or near the optimum with regard to efficiency [1], [2], whereby these optima depend considerably on firing temperatures. The higher the firing temperature, the higher the pressure ratios required. At such pressure ratios, the use of regeneration brings only a small improvement in efficiency, if any. From a certain pressure ratio upwards, regeneration is entirely impossible, since the temperature after the compressor is higher than the temperature of gases after their expansion in the turbine (Figures 1 to 3).

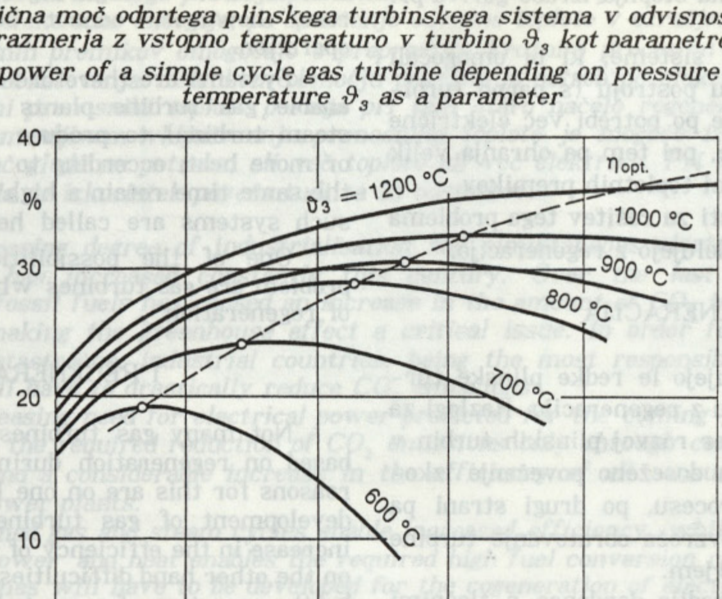
Figure 4 shows how much the efficiency can be improved in case of a plant with a regeneration system.

According to this figure, the efficiency of a plant with a gas turbine with a low pressure ratio can be considerably improved with the mere addition of regeneration. It can be improved even



Sl. 1. *Specifična moč odprtega plinskega turbinskega sistema v odvisnosti od tlačnega razmerja z vstopno temperaturo v turbino ϑ_3 kot parametrom*

Fig. 1. *Specific power of a simple cycle gas turbine depending on pressure ratio with firing temperature ϑ_3 as a parameter*



Sl. 2. *Električni izkoristek η_e pri odprtem plinskem turbinskem procesu*

η_v = 0,84 kompresor, η_T = 0,88 turbina, $\eta_{Br.}$ = 0,97 zgorevalna komora, $\eta_{mechn.}$ = 0,99, ϑ_3 = vstopna temperatura

Fig. 2. *Electrical efficiency η_e for simple gas turbine cycle*

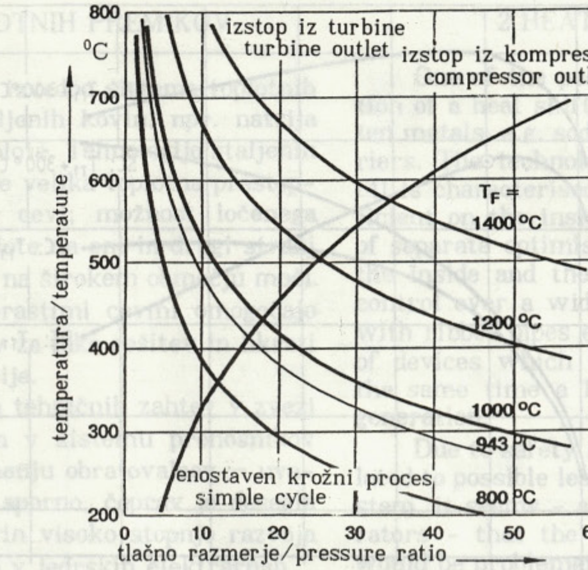
η_v = 0,84 compressor, η_T = 0,88 turbine, $\eta_{Br.}$ = 0,97 combustion chamber, $\eta_{mechn.}$ = 0,99, ϑ_3 = firing temperature

optimiranjem tlačnega razmerja, tako da se doseže vrh funkcije ali pa tako, da se dvigne vstopna temperatura v turbino in hkrati prilagodi tlačno razmerje tej temperaturi. Z uvedbo optimiranih plinskih turbin z visokimi vstopnimi temperaturami v turbino je mogoče doseči izboljšanje izkoristka za nadaljnjih 15 do 20 odstotkov (sl. 5).

Slika 6 prikazuje medsebojno odvisnost električne energije in izkoristka od tlačnih izgub na strani zraka in odpadnih plinov pri plinski turbini podjetja EGT, tip M 5352 R.

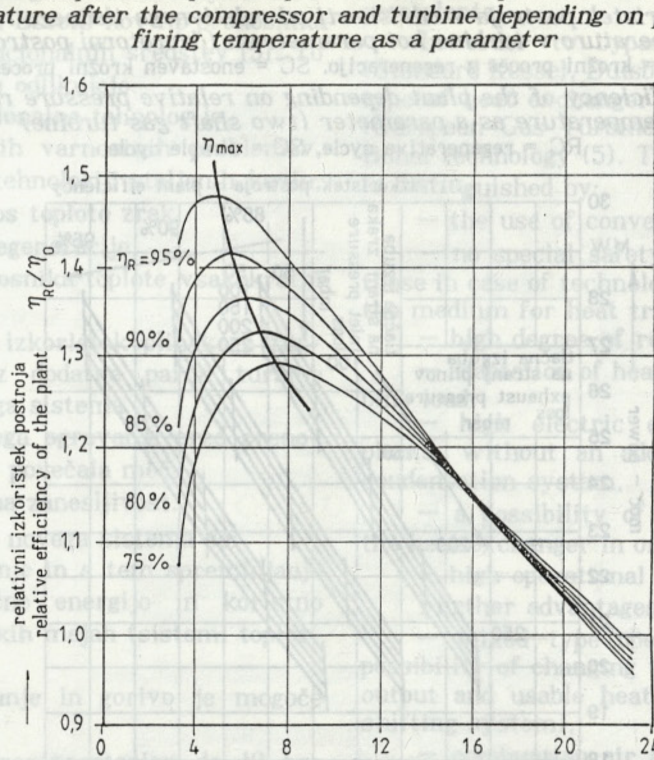
more by optimising the pressure ratio, by achieving the peak of the function or by increasing the firing temperature and simultaneously adapting the pressure ratio to it. With the introduction of optimised gas turbines with high firing temperatures, a further improvement in efficiency of 15 to 20% can be achieved (Fig. 5).

Figure 6 shows the mutual dependence of electric power and efficiency on pressure loss in the air and exhaust gas ducts, using the example of an M 5352R type EGT gas turbine.



Sl. 3. *Temperatura za kompresorjem in turbino v odvisnosti od razmerja tlakov in s temperaturo pri vstopu v turbino kot parametrom*

Fig. 3. *Temperature after the compressor and turbine depending on pressure ratio and firing temperature as a parameter*

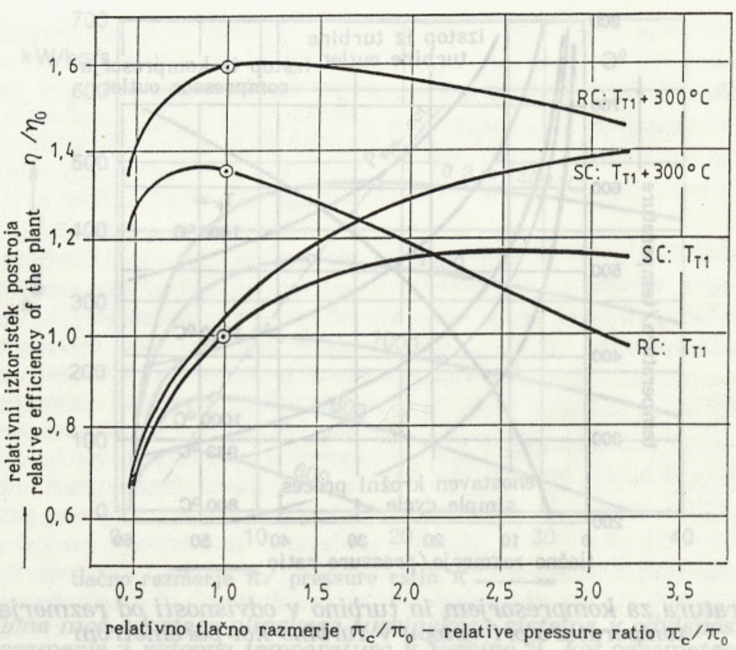


Sl. 4. *Relativni izkoristek postroja v odvisnosti od tlačnega razmerja s stopnjo regeneracije kot parametrom (dvorotorni stroj)*
RC = krožni proces z regeneracijo, η_R = stopnja regeneracije

Fig. 4. *Relative efficiency of a plant depending on pressure ratio, with the degree of regeneration as a parameter (two-shaft gas turbine)*
RC = regenerative cycle, η_R = degree of regeneration

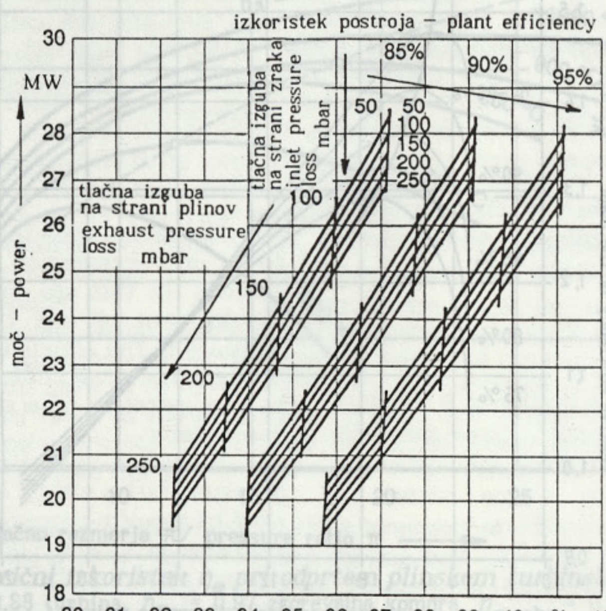
Za kakovost plinskih turbinskih procesov z regeneracijo je najpomembnejša tlačna izguba na strani plinov, ker ima ta velik vpliv na električno moč in izkoristek. Tlačne izgube na zračni strani imajo le majhen vpliv, zato je mogoče na tej strani doseči s primerno zasnovo veliko toplotno prestopnost.

Pressure loss in exhaust gas ducts is most important for the quality of gas turbine processes, since it has a large influence on output power and efficiency. Pressure loss in air inlet duct has only a small influence on power output and efficiency, therefore with appropriate design a high heat transfer coefficient can be achieved.



Sl. 5. *Relativni izkoristek postroja v odvisnosti od relativnega tlačnega razmerja z vstopno temperaturo v turbino kot parametrom (dvorotorni postroj)*
RC = krožni proces z regeneracijo, SC = enostaven krožni proces

Fig. 5. *Relative efficiency of the plant depending on relative pressure ratio, with firing temperature as a parameter (two shaft gas turbine)*
RC = regenerative cycle, SC = simple cycle



Sl. 6. *Moč M 5352R v odvisnosti od izkoristka postroja*
Fig. 6. *Power of M 5352R depending on plant efficiency*

Standardni regeneratorji so zelo občutljivi za hitre spremembe obremenitve (tudi med zagonom in ustavitvijo). Termične napetosti, ki pri tem nastajajo, povzročajo razpoke in puščanje, kar zmanjšuje izboljšanje izkoristka, ki bi ga sicer mogli doseči z regeneratorjem. Šele z uvajanjem uspešnih in prilagodljivih sistemov prenosa toplote, bi postale zasnove plinskih turbin z majhnimi tlačnimi razmerji in z regeneracijo upravičene.

Classical regenerators are very sensitive to rapid changes in load (including start-up and shut-down). Thermal stresses which occur during these processes cause cracks and leakage, thus reducing the improvement in efficiency that could otherwise be achieved with a regenerator. Only with the introduction of successful and flexible systems for heat transfer would the design of gas turbines with low pressure ratios and regeneration become reasonable again.

2 SISTEMI TOPLOTNIH PREMIKOV

Ena od možnosti za izvedbo sistema toplotnih premikov je uvedba staljenih kovin, npr. natrija ali kalija kot nosilcev toplote. Tehnologijo staljenih kovin [1], [3], [4] odlikuje velika toplotna prestopnost na notranji strani cevi, možnost ločenega optimiranja prestopa toplote na eni in drugi strani cevi in prožna regulacija na širokem območju moči. Prenosniki toplote z rebrastimi cevmi omogočajo poceni oblikovanje naprav za tako rešitev in hkrati visoko stopnjo regeneracije.

Zaradi varnostnih in tehničnih zahtev v zvezi z morebitnim puščanjem v sistemu prenosnikov toplote pa se zdi – po mnenju obratovalcev – uvajanje takšnjih sistemov sporno, čeprav je dosegla tehnologija staljenih kovin visoko stopnjo razvoja in jo uspešno uporabljajo v jedrskih elektrarnah.

Da bi obšli te probleme, so razvili pri SKG (Standard Kessel, Duisburg) v sodelovanju z EGT (European Gas Turbines, Essen) nov tip prenosnika toplote z uporabo konvencionalnih sredstev [5]. To vrsto prenosnika toplote odlikujejo:

– uporaba konvencionalne tehnologije,

– da nima posebnih varnostnih problemov, kakršni se pojavijo pri tehnologiji staljenih kovin, ker je sredstvo za prenos toplote zrak,

– visoka stopnja regeneracije,

– prilagajanje prenosnika toplote vsakokratni obremenitvi turbine,

– velik električni izkoristek plinskega turbinskega postroja, brez dodatne parne turbine oziroma kondenzacijskega sistema.

– možnost dodatnega ogrevanja pred prenosnikom toplote, da bi se povečala moč,

– velika obratovalna zanesljivost.

Nadaljnje prednosti novega sistema so:

– mešano obratovanje in s tem spreminjanje razmerja med električno energijo in koristno toploto je mogoče v širokih mejah (sistemi toplotnih premikov),

– zrak za zgorevanje in gorivo je mogoče močno (pred)greti.

Obratovalni tlaki regeneratorjev do 10 bar dopuščajo pri zasnovi sistemov podobna razmišljanja kakor pri zasnovi parnih kotlov. Prenosnik toplote je zato mogoče celo vključiti v kotel.

3 KONSTRUKCIJSKA REŠITEV

Slika 7 prikazuje sestav nekega takega sistema toplotnih premikov s priključenim parnim kotlom na odpadno toploto za daljinsko ogrevanje. S tripotnim regulacijskim ventilom se zračni tok prenosnika toplote tako naravnava, da se vsakokratna potreba po toploti pokriva z ustrezno sprostitvijo toplote v sistemu.

2 HEAT SHIFTING SYSTEMS

One of the possibilities for the implementation of a heat shifting system is the use of molten metals, e.g. sodium or potassium, as heat carriers. The technology of molten metals [1], [3], [4] is characterised by a high heat transfer coefficient on the inside of the pipes, the possibility of separate optimisation of heat transfer on both the inside and the outside of pipes and flexible control over a wide load range. Heat exchangers with ribbed pipes enable inexpensive construction of devices which employ such solutions and at the same time a large heat transfer during regeneration.

Due to safety and technical requirements related to possible leakage in the heat exchanger system, it seems - according to the opinion of operators - that the introduction of such systems would be problematic, even though the technology of molten metals has reached a high level of development and is used successfully in nuclear power plants.

In order to bypass these problems, SKG (Standard Kessel, Duisburg) have developed a new type of heat exchanger in cooperation with EGT (European Gas Turbines, Essen), using conventional technology [5]. This type of heat exchanger is distinguished by:

– the use of conventional technology,

– no special safety problems occur such as those in case of technology of molten metals, since the medium for heat transfer is air,

– high degree of regeneration,

– adaptation of heat exchangers to actual turbine load,

– high electric efficiency of gas turbine plants, without an additional steam turbine or condensation system,

– a possibility of additional firing ahead of the heat exchanger in order to increase power,

– high operational reliability.

Further advantages of the new system are:

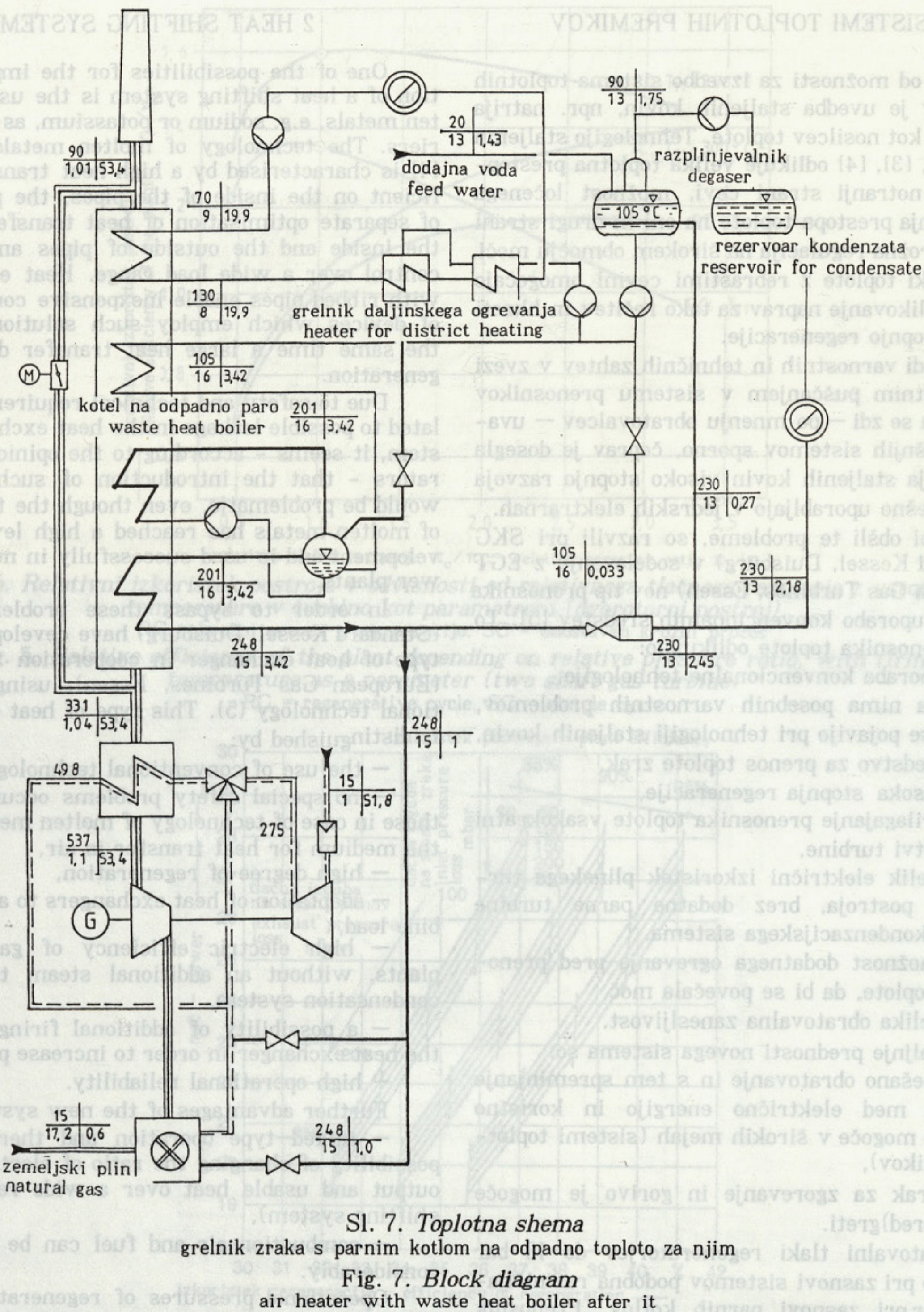
– mixed–type operation and therefore the possibility of changing the ratio of electric power output and usable heat over a wide range (heat shifting system),

– combustion air and fuel can be preheated considerably.

Operational pressures of regenerators up to 10 bar allow similar design as used for boilers and steam systems. Heat exchangers can even be integrated in the boiler.

3 DESIGN SOLUTION

Figure 7 shows the structure of one of such heat shifting systems with an integrated waste heat boiler for district heating. Three-way control valve of the air flow entering the heat exchanger enables the heat requirements to be covered each time by appropriate heat production.



Sl. 7. *Toplotna shema*
grelnik zraka s parnim kotlom na odpadno toploto za njim

Fig. 7. *Block diagram*
air heater with waste heat boiler after it

V času najmanjše potrebe po toploti poleti (električni izkoristek) teče skozi prenosnik toplote polni zračni tok iz kompresorja plinske turbine, medtem ko teče pozimi, ko je potreba po toploti največja (najmanjši električni izkoristek), zračni tok naravnost v gorilnik plinske turbine.

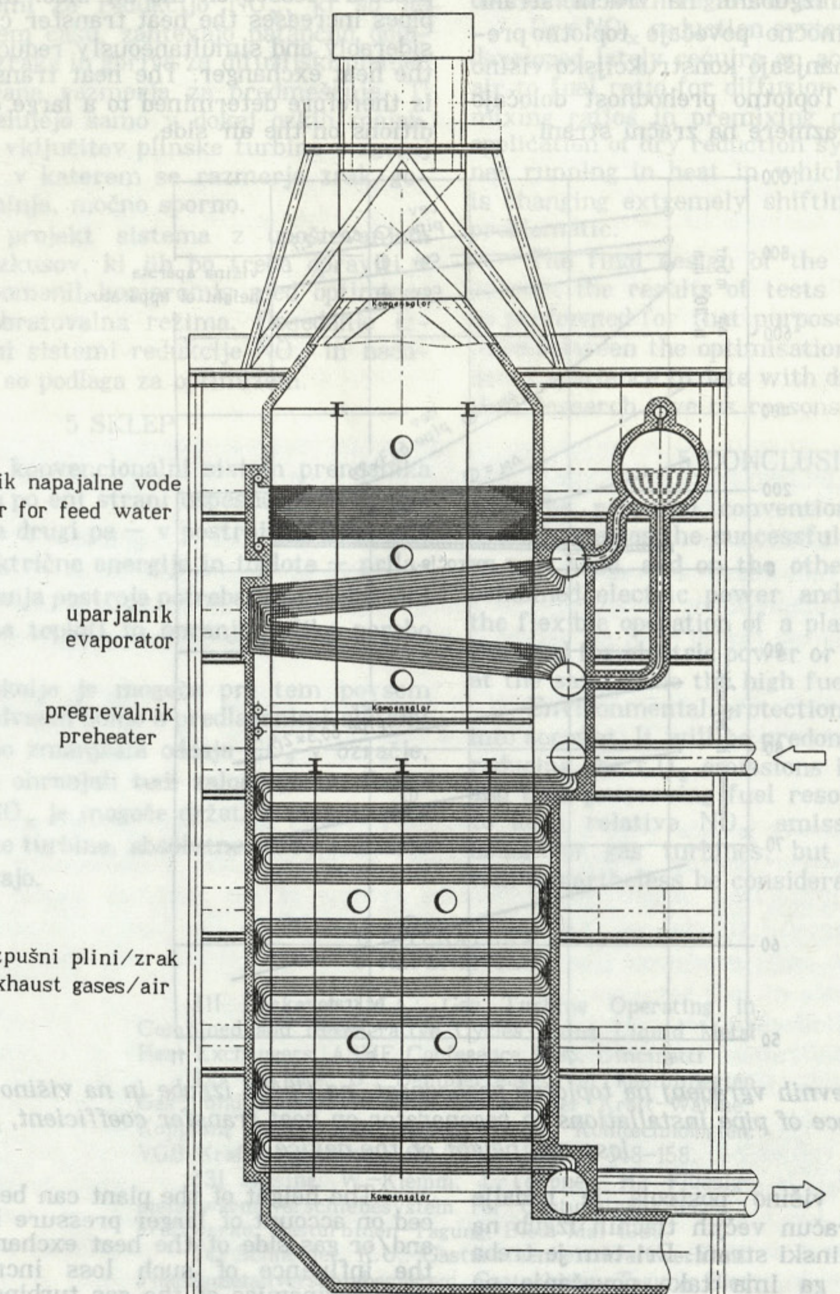
Prenosnik toplote se v tem zadnjem primeru ne hladi, zato mora biti material za cevi prenosnika toplote tako izbran, da prenaša tudi najvišje temperature izpušnih plinov plinske turbine brez škode.

During the time of lowest heat requirements in summer (maximum electric efficiency), full air flow flows from the compressor of a gas turbine through the heat exchanger, while in winter, when the heat requirements are highest (lowest electric efficiency), air flows straight into the combustion chamber of a gas turbine.

The heat exchanger in this last case is not cooled; the material used for the heat exchanger pipes must therefore be chosen such that it can withstand the highest temperatures in the gas turbine exhaust without damage.

Konstrukcijsko zasnovo takega sistema toplotnih premikov prikazuje slika 8. Gladke cevi so na ploščah tako obešene, da se lahko pri vsaki obtežbi postroja prosto raztegnejo. Na zračni strani dopuščeni večje tlačne izgube (v primerjavi z atmosferskimi postroji) omogočajo optimalno oblikovanje površin za ogrevanje zraka.

The design of such a heat shifting system is presented in Figure 8. Smooth pipes are suspended in plates in such a manner that they can expand freely under each loading of the plant. Higher allowable pressure losses an the air side (in comparison with atmosperic pressure level heat exchangers) enable optimal design of air heating surfaces.



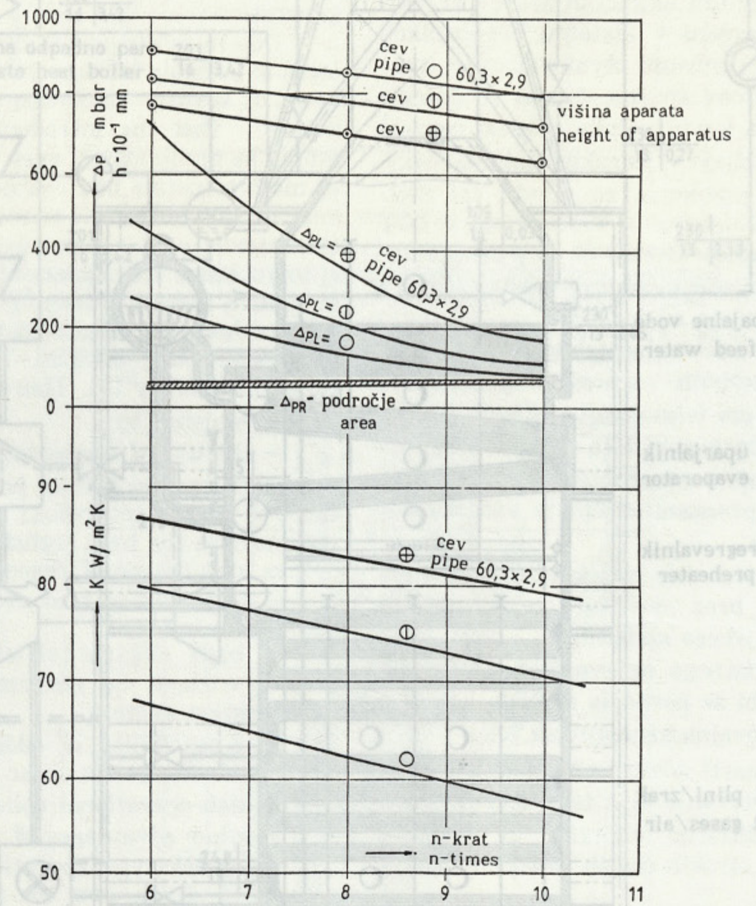
Sl. 8. *Grelnik zraka s priključenim parnim kotlom na odpadno toploto*
parametri pare: 240 °C, 15 bar, poleti: 13.3 t/h, pozimi: 33 t/h
Fig. 8. *Air heater with connected waste heat boiler*
steam parameters: 240 °C, 15 bar, in sommer: 13.3 t/h, in winter: 33 t/h

Visok zračni tlak omogoča, da ima tok v cevეh veliko masno gostoto pri zmernih toplotnih prehodnostih, kakor je običajno pri gradnji parnih kotlov.

Slika 9 kaže toplotne prehodnosti v odvisnosti od standardnih hitrosti zraka znotraj gladkih cevi. Vrednosti za *k* določa v osnovi hitrost zraka z ustreznimi tlačnimi izgubami na zračni strani. Vložki znotraj cevi močno povečajo toplotno prehodnost in hkrati zmanjšajo konstrukcijsko višino prenosnika toplote. Toplotno prehodnost določajo torej v veliki meri razmere na zračni strani.

High air pressure enables the air in the pipes to have a high mass density at moderate heat transfer coefficients, as is usual in the design of steam boilers.

Figure 9 shows heat transfer coefficients depending on standard air velocities inside smooth pipes. The quantity of k is basically determined by the velocity of air with appropriate pressure losses on the air side. Insertions inside pipes increases the heat transfer coefficient considerably and simultaneousl y reduce the height of the heat exchanger. The heat transfer coefficient is therefore determined to a large extent by conditions on the air side.



Sl. 9. *Vpliv cevnih vgradenj na toplotno prehodnost, na tlačne izgube in na višino naprave*

Fig. 9. *Influence of pipe installations in regenerator on heat transfer coefficient, pressure loss and height of the device*

Konstrukcijsko višino postroja je nadalje mogoče znižati na račun večjih tlačnih izgub na zračni oziroma na plinski strani. Pri tem je treba paziti na vpliv, ki ga ima tako povečanje na termodinamiko plinskega turbinskega procesa.

The height of the plant can be further reduced on account of larger pressure loss on the air and/or gas side of the heat exchanger. However, the influence of such loss increases on the thermodynamics of the gas turbine process have to be taken into account.

4 EMISIJE

Če pregledamo emisije plinskih turbinskih postrojev, izvedenih z opisanim sistemom toplotnih premikov, ugotovimo na primeru emisij NO_x, da tu nastane povsem nova slika. Če si že želimo prilagodljivost postroja, pa le ne smemo spregledati, da je temperatura zgorevalnega zraka 150 do 250 °C višja kakor v kombiniranem procesu,

4 EMISSIONS

A review of emissions from a gas turbine plant, fitted with the described heat shifting system, shows an entirely new situation, for NO_x emissions for example. As much as flexibility of the plant is desirable, one must not neglect the fact that the temperature of combustion air is 150 to 250 °C higher than in a combined s čimer se bistveno spremeni proces zgorevanja pri isti plinski turbini, pač glede na to, v kakšnem režimu trenutno obratuje.

Da bi mogli v celoti izkoristiti prednosti opisanega sistema toplotnih premikov, mora gorilnik prenesti obe vrsti obratovanja in vse njune kombinacije. Zato mora biti sistem prilagodljiv tudi glede emisij.

Suhi sistemi za redukcijo NO_x, ki so jih razvili v zadnjem času, zahtevajo natančno določeno razmerje zraka in goriva za difuzijski plamen in ozko definirana razmerja za predmešanje. Ti suhi sistemi delujejo samo v dokaj ozkih mejah. Potemtakem je vključitev plinske turbine v zgoraj opisani sistem, v katerem se razmerje zrak/gorivo zelo spreminja, močno sporno.

Dokončen projekt sistema z upoštevanjem rezultatov preizkusov, ki jih bo treba opraviti v ta namen, bo pomenil kompromis med optimiranjem za oba obratovalna režima. Dosedanje izkušnje s suhimi sistemi redukcije NO_x in nadaljnje raziskave so podlaga za optimizem.

5 SKLEP

Predlagani konvencionalni sistem prenosnika toplote omogoča po eni strani uspešno izkoriščanje regeneracije, na drugi pa — v postrojih s povezano proizvodnjo električne energije in toplote — prilagajanje obratovanja postroja potrebam po električni energiji oziroma toploti in ohranja veliko porabo goriva.

Skrb za okolje je mogoče pri tem povsem upoštevati. Predvsem bomo s predlaganimi sistemi dosegli, da se bo zmanjšala oddaja CO_2 v ozračje, s tem pa bomo ohranjali tudi zaloge goriv. Relativne emisije NO_x je mogoče držati v mejah, običajnih za plinske turbine, absolutne pa se vendarle občutno zmanjšajo.

cycle, which causes a significant change in the combustion process for the same gas turbine, depending on what operation regime is currently in progress.

In order to be able to fully exploit the advantages of the described heat shifting system the combustor must allow both operational modes and all combinations. The system must therefore also be flexible with regard to emissions.

Dry NO_x reduction systems which have been developed lately require an accurately determined air to fuel ratio for diffusion flame and a narrow mixing ratios in premixing mode. Therefore the application of dry reduction systems on gas turbines running in heat in which the air/fuel ratio is changing extremely shifting systems, is very problematic.

The final design of the system taking into account the results of tests which will have to be performed for that purpose will be a compromise between the optimisation of operational modes. Experience to date with dry systems and further research give us reasons for optimism.

5 CONCLUSION

The proposed conventional heat exchanger system enables the successful use of regeneration on one hand, and on the other — in plants with combined electric power and heat production — the flexible operation of a plant in order to meet the need for electric power or heat, and maintains at the same time the high fuel conversion rate.

Environmental protection can be fully taken into account. It will be predominantly achieved by reducing the CO_2 emissions into the atmosphere and thus preserving fuel resources. It is possible to keep relative NO_x emissions within limits usual for gas turbines, but absolute emissions will nevertheless be considerably reduced.

6 LITERATURA
6 REFERENCES

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