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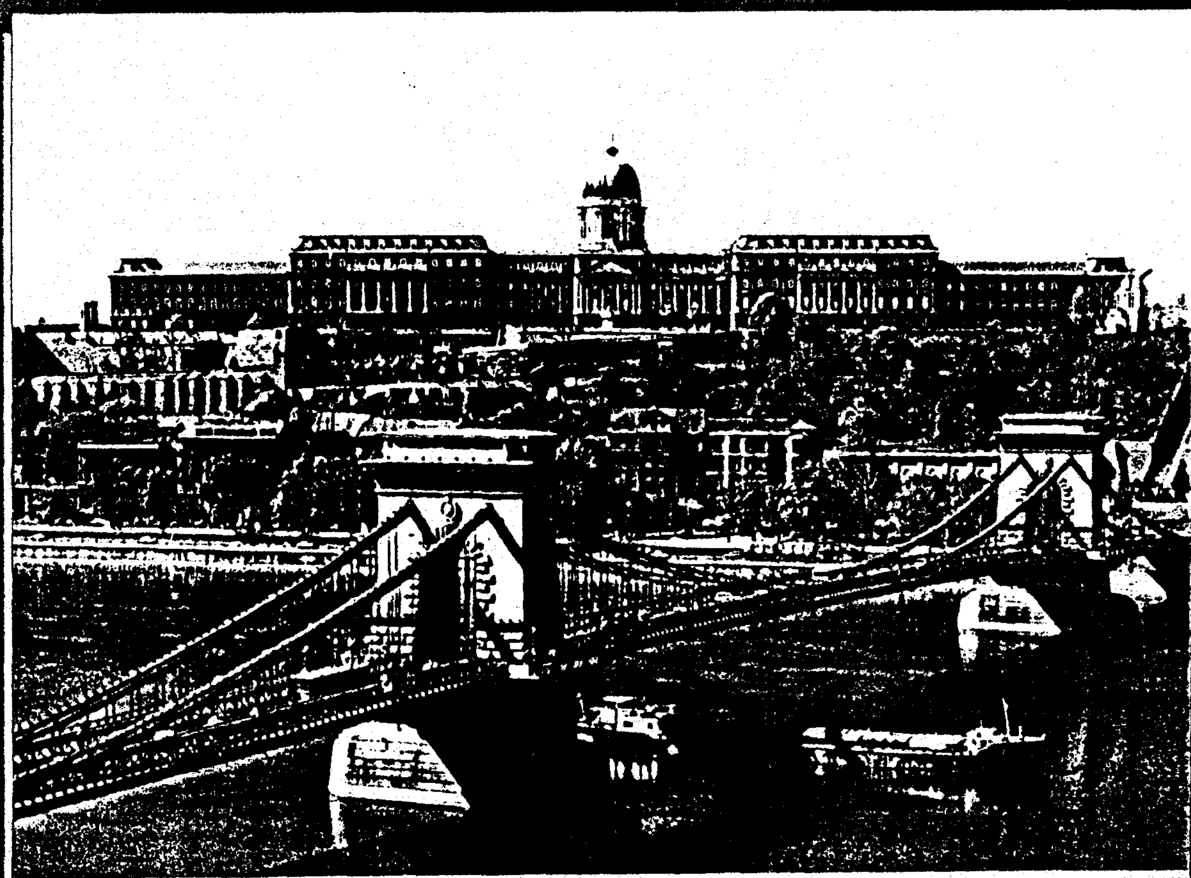

PROCEEDINGS

Application of Process Integration for Energy Saving and Pollution Reduction in Ukraine

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ABSTRACT

The minimisation of energy consumption for existing industries is vital in the conditions of energy crisis. For such conditions, the estimating of real energy consumption and targeting for its decreasing is the very important for sites and plants. It includes the development of optimal ways for the energy saving retrofit with using the methods of Process Integration. The results of implementing of the Process Integration in Ukraine gave a fruitful output. Now the another step is to use the heat exchangers of high effectiveness for optimal heat exchangers networks. The implementing of plate heat exchangers lets to save the investments, energy consumption and to improve the performance in industrial heat exchange networks. Compared with shell and tube ones plate heat exchangers are very compact and have a higher degree of efficiency.

INTRODUCTION

The problem of energy conservation is very important in condition of energy crisis in Ukraine and because most of operating plants were built at the time when the cost of energy resources was relatively low. Many plants were designed about 1950-70 so energy saving was not of such significance as now.

Generally industry gives a negative environmental impact and to achieve sustainable development it a totally new way of thinking has to be applied towards all industrial processes, especially energy based systems. Various required changes made to the operation of processes may require retrofit of the existing heat exchangers networks (HEN). These changes frequently involve process debottlenecking combined with the improvement in process energy efficiency. Analysis and synthesis of HEN is a part of a larger problem - analysis and synthesis of industrial production processes.

Pinch Analysis concepts, pioneered at DPI UMIST (Linnhoff et al, 1982, 1983, 1988, 1994 and Smith, 1994) and recently Asante and Zhu (1997), made a substantial contribution to energy saving technologies. It is possible to set targets for improvements of individual processes as well as of overall production site. The largest and most complex total site may be presented (Klemes et al, 1994, 1997) in manageable graphical representation. The techniques of Pinch Analysis are very efficient for analysis, optimal design and retrofit (Zhu, 1997) of HENs. The Pinch analysis sets targets before the design and any improper matches of hot and cold streams in heat exchangers can be avoided. This excludes the danger of poor utilisation of temperature driving forces with interacting of very hot streams with streams at low temperatures. The result is the creation of a HEN that reaches the minimum energy consumption. They were numerous successful applications in different industries (Bohacek at al, 1996, Hufendiek and Klemes, 1996, Hassan, Klemes and Plesu, 1998).

As a result of retrofit studies, additional surface area may be required for some heat exchangers. There are a number of options to provide additional area, such as installing new shells or new units, adding new pipes to an existing bundle etc. In practice, techniques of heat transfer enhancement has not been applied extensively due to limited understanding of these techniques and some potential difficulties in operation.

However, Heat Transfer Enhancement techniques are very promising in reducing capital cost and implementation time while applied to HEN retrofit (Zhu, Zanfir and Klemes, 1998).

The use of heat transfer enhancement for increasing heat exchange capacity of the existing heat transfer area within a network can avoid or reduce additional area required. This makes the retrofit modification quick and cheap to implement. Thus, heat transfer enhancement can become an attractive alternative in retrofit modifications due to the capital and installation cost reduction (Zhu, Zanfir and Klemes, 1999).

Another significant step is to supply such HEN with optimal elements; heat exchangers that are effective, flexible, compact, safe and easy for cleaning. In other words, heat exchangers have to lead to the most profitable trade-off between minimisation of consumption and increasing of heat exchange area.

Plate heat exchangers which operate at very high overall heat transfer coefficients, have very high compactness, flexibility may be widely used for the case mentioned above.

PRINCIPLE PHE PERFORMANCE

PHE consists of a number of corrugated plates of which the most efficient and widely used are "herringbone" or "chevron" plates. The corrugations are located with the angle to its vertical axis and the plates are assembled so those peaks on adjacent plates are crossing one another and are in contact. The construction and basic operating principles are well described in the literature (Baranovski, 1973, Marriot, 1977, Bond, 1981).

Such construction of plate causes the channels of complex geometry that provides high level of induced turbulence and therefore high heat transfer coefficients up to 6000-8000 W/m^2 K. Numerous experiments gave appropriate derivations for calculation of film heat transfer coefficients and for pressure drop. The results proved the correctness of the analogy method proposed by von Karman and Martinelli (Tovazhnyanski and Kapustenko, 1984). Therefore, the calculation of performance for PHE with different corrugated plates is possible.

This is the base of the optimal synthesis of the corrugated heat Transfer surface for plates that are the main part of PHE. It lets to rise to higher level: synthesis of the system of PHEs.

SUCCESSFUL INDUSTRIAL APPLICATIONS

District Heating Systems (DHS)

Process integration of big boiler house with opened district heating system was described in (Tovazhnyanski et al, 1998). The "bottleneck" of such DHS is the water treatment unit in boilerhouse. The real consumption of heat here is about 20-40% of total energy consumption.

Introduction of tap water system where tap water is heated with DH hot water from closed circuit supplied from boilerhouse lets to reduce feed flow to boilerhouse. This heating has to have place in heat exchangers. Such kind of network eliminates the using of DH water as domestic hot water so the amount of feed water will be significantly decreased.

The Composite Curves for "opened" and "closed" DHS are presented in Fig 1 and 2 respectively. The energy saving is about 30%.

It is clear that total heat consumption decreased from 165 MW to 114 MW, ie energy saving is about 30%. However, the amount of heat for municipal needs (capacity of district heating system) is not changed. Therefore, the construction of the composite curves give us the simple and trustworthy method of estimating of DHS energy consumption. Now such method used for pre-project economical calculation in case of retrofit the "boilerhouse + DHS" systems in Ukraine.

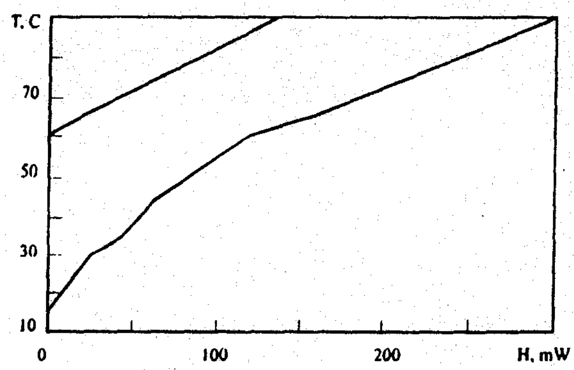

Figure 1.

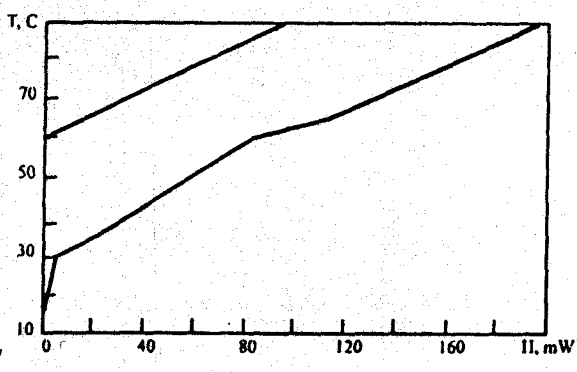

Figure 2.

The key instrument in DHS retrofitting is using the modern and effective equipment. PHE assembled with controllers and noiseless circulation pumps is the extremely compact and effective heat substation. The compactness lets to install these heat substations in existing technical rooms of buildings. Such installations with traditional in Ukraine shell-and-tube heat exchangers are impossible, so we have the significant decreasing of the investments for DHS retrofit.

These heating substations produce instantaneous heat tap water for apartment, administrative houses, schools etc. The system comprises two major circuits: the primary circuit for DH water from boiler house and the secondary circuit for the tap water (see Fig. 3).

The using of these heat substation lets to do next step: to integrate into DH system the heat of district heating water returning from radiators to preheat the cold tap water from 5 °C to 32-35 °C. In Fig. 3 the PHE consist of two stages: first stage 1 uses the heat of district heating water from radiators (DH(R) in Fig. 3) and the second stage 2 uses the heat of district heating water supply from boiler house. Both stages are constructed as a usual PHE with two passes. The temperature control changes the flow of DH water supply depending on hot tap water consumption. The heat substation mentioned above comprise all possible energy saving elements. Such construction of PHE (two stages on one frame) is the pioneering one for Ukrainian DHS.

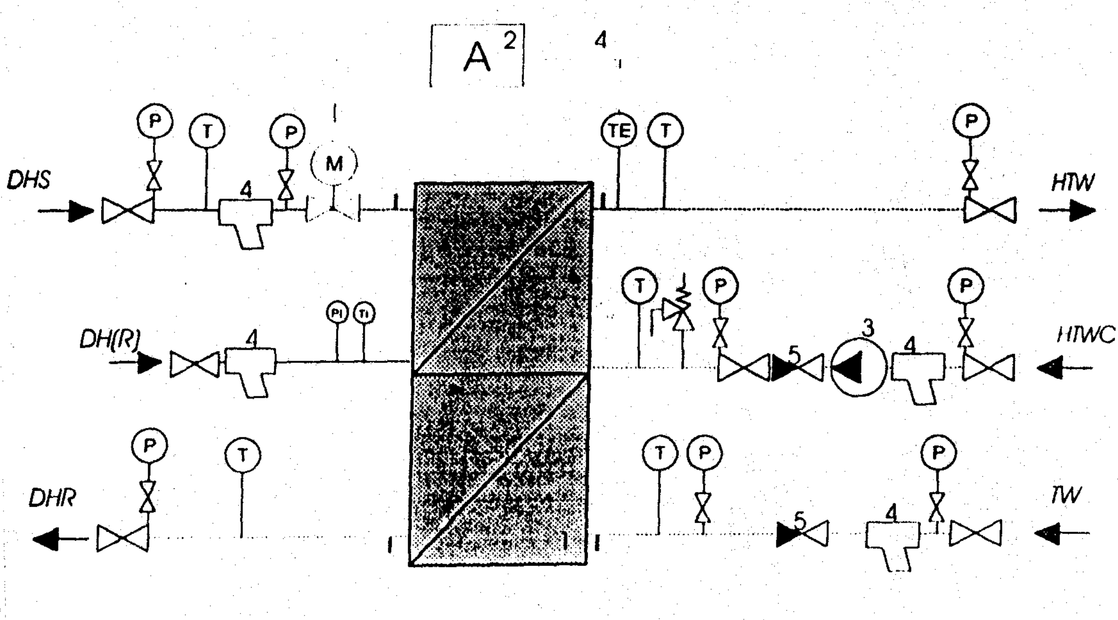

Figure 3. Heat substation for preparing of hot tap water based on plate heat exchanger.

1-2 – plate heat exchanger; A^2 – automatic temperature controller; 3 – circulating pump; 4 – strainer; 5 – check valve; M – control valve with servomotor; TE – temperature sensor; T – thermometer; P – manometer; DHS – district heating water supply; DH(R) – district heating water from radiators; DHR – district heating water return; TW – cold tap water; HTW – hot tap water, HTWC – hot tap water circulation line.

Such heat substation now producing by AO SOGRUGESTVO – T company.

The retrofit of DHS of one East Ukrainian cities (boiler house capacity 30 MW) from "opened" to "closed" system was done with using of 34 heat substations based on PHEs. The energy saving was estimated more than 200 USD per annum with payback period 8 months.

Chemical Industry

The problem of the debottlenecking of the monoethanolamin (MEA) purification unit in the high capacity ammonia plant had been solved. The significant part of this unit is the recuperative heat exchangers system between absorber and regenerator of ME-absorbent. The maximum temperature of regenerated MEA-absorbent is about 130°C, pressure difference between fluids is about 2.5-3.0 MPa, and demanded mass flow is up to 200 kg/s.

The existing network included 10 shell-and-tube heat exchangers with total heat exchange area F=3800 m² had not provided the demanded parameters of the MEA-purification unit. For the mentioned conditions the usual gasketed PHE is not possible to operate. Therefore, the special PHE was designed. It is all-welded pack of plates with external collectors, which are welded to pack of plates. The arrangement of channels is multipass and arrangement of fluid is cross-flow within single pass but countercurrent flow for all unit. Such principle provides the decreasing of pressure drop because the inlet to channel is opened at all width of the plate. The network with six such plate heat exchangers had been installed with the total surface area 1920 m². The optimal arrangement of these units is parallel.

The implementation of this optimal PHEs' network lets to provide the demanded amount of absorbent in the purification unit, to decrease the temperature in absorber and the emission of the heat to atmosphere in air coolers. The optimal parameters of corrugated plates were defined too.

PHE for Ammonia Synthesis Column

The process ammonia synthesis takes place inside the special shell (synthesis column). The temperature of process is usual about 400-500°C and the pressure is about 300 kg/s m². Inside shell the basked with catalyser and preheater of process gas mixture are disposed.

Developed special PHE as a such preheated is the special designed all-welded unit with horizontal pack of corrugated circle plates and with special channel for the flow of bypass gas (Tsareva, Tovazhnyanski and Orlova, 1997).

The compactness of such PHE unit lets to enlarge the length of basket with catalyser and to decrease the total pressure drop of column. Consequently the increasing of syntheses ammonia output was obtained and decreased the energy consumption for compression.

Food and Drink Industry

They have been published some successful PI industrial case studies considerably reducing the energy consumption in the food and drink industry (Hufendiek and Klemes 1996, Klemes, Kimenov and Nenov, 1998).

The application of PHEs in heat recovery systems allows significantly increase the recovery because of decreasing of the minimum allowed temperature difference (ΔT_{min}) in this heat exchangers. In PHEs the minimum temperature difference may be as small as 1-3 °C. It is very important for heat transfer from hot streams in the bottom part of Composite Curves. In food industry many products are to be chilled to temperatures close to 0 °C. In this case tubular heat exchangers would be very large and some special fluids, for example brine, has to be used. Using PHEs may help to exclude the brine and to use only ice chilled water. It decreases the energy consumption for chilling.

The application of PI method in one of the Kharkiv breweries for HENs retrofit gives the possibility to use several optimal PHEs. In producing the temperance drinks the cooling of sugar syrup may be done not with brine but with ice water in PHE. It lets completely to remove the aggressive brine from cooling system of brewery and decrease energy consumption of chilling unit.

The integration of secondary vaporous from brewing boilers gives the possibility to save 2.5 MW of heat. This heat is using for preparing of 36.5 tons per hour of hot water with temperature about 70 °C for needs of brewery. This water is heating in PHE with heating surface 20 m^2.

The implementation of process integration methods with using of modern PHEs may decrease the energy consumption from 22.7 MJ per decalitre to 12.6 MJ per decalitre. Saving of power consumption is 20%, saving of water consumption is 40%.

CONCLUSIONS

1. The incorporation of the potential of Pinch technology in the optimal heat exchange network development is very promising and enables a new quality of plant engineering systems optimisation to be achieved.

2. The use of plate heat exchangers as elements of optimal heat exchange network is the way to profitable trade-off between minimisation of energy consumption and the amount of capital costs.

3. There is a strong demand for the technology transfer and extending the energy saving know-how into the other industries in Ukraine. The vital vehicle for the future research and demonstration studies is going to be an EU INCO-COPERNICUS project "Sustainable |Development by Retrofit and Debottlenecking for Energy Based Systems – REDBAS".

ACKNOWLEDGEMENT

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SYMBOLS

DH	district heating
DH(R)	district heating water from radiators
DHR	district heating water return
DHS	district heating water supply
DHS	district heating systems
HEN	heat exchanger network
HTW	hot tap water
HTWC	hot tap water circulation line
MEA	monoethanolamin
P	manometer
PHE	plate heat exchanger
PI	process integration
T	thermometer
TE	temperature sensor

TW cold tap water
ΔT_{min} minimum allowed temperature difference

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