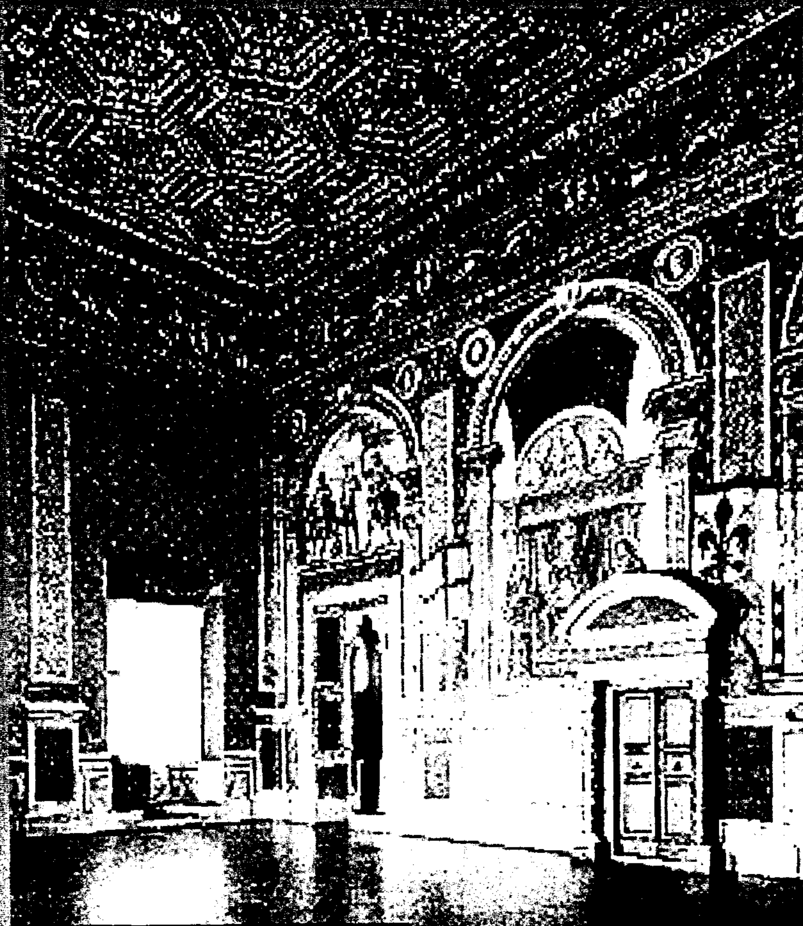

ICheaP-5

4th Conference
Process Integration,
Modelling and Optimisation
for Energy Saving and
Pollution Reduction

5th Italian
Conference
on
Chemical and
Process Engineering

Florence 20-23 May 2001

Organized by AIDIC

Proceedings

PRES'01

THE HEAT INTEGRATION IN PROCESS OF PRODUCING THE PITCH FROM COAL TAR

L.L.Tovazhnyanskyy, P.Î.Kapustenko, L.M.Ulyev, S. Boldyrev[1], V. V. Djelali[2], V.N. Rubchevskyy[3], V.M. Volokh[3]

Department of Chemical. Engineering, National Technical University "KhPI", Frunze St. 21, 61002, Kharkiv, Ukraine; Tel.: +380 572-400-893, Fax: +380 572-400-632, E-mail: ulm@kpi.kharkov.ua
[1]AO SODRUGESTVO – T, Frunze St. 21, 61002, Kharkiv, Ukraine; Tel.: +380 572-400-523, Fax: +380 572-475-513, E-mail: kap@kpi.kharkov.ua
[2] Ukraine Coal Fuel Chemistry Institute, Kharkiv; [3] Coke – Oven Plant "JSC" ZAPOROZHKOKS, Zaporozhie

Introduction

The coking has obtained more wide spread occurrence among all types of the solid fuel conversions. In Ukraine because of highly developed Metallurgy Industry 14 Coke-Oven Plants have been set in operation. All the plants were designed and built at the time of rather chip energy resources and now all this plants, as a rule, are working far from optimum performance.

Therefore, in view of the energy resources became greatly expensive in the world market (Stork, 2001a,b), the question of Energy Saving is the one of survival questions actually for all Ukrainian plants, and particularly for Coke-Oven Plants.

The primary products of coking are fixed residue – coke and coal-volatile matter – coke-oven gas, which then is divided by condensation into coal tar and crude benzene. The coal tar has rich structure and it is the most valuable basic material for Chemical Industry. With the purpose of further utilization the coal tar is divided into fractions. Toward this the distillation section exists in all Ukrainian coke-oven plants.

Let's examine the technological scheme of distillation, which is typical for Ukraine (Fig. 1). Tar with temperature about 343…348 K is given from the storehouse to the convection level of pipe furnace (Fig. 1), where it is heated to temperature ~ 393 K and supplied to the evaporator No. 4 (Fig. 1) for dehydration. The evaporator steam is cooled and supplied to the separator (Fig. 1). The dehydrated tar is pumped through radiant section of pipe furnace where it is heated for single evaporation in the pitch column No. 7 (Fig. 1). The pitch from lower section of column is supplied along the pitch main in the pressure tank of the pitch store or for preparation of coke-pitch plant. The first and second anthracene fractions are taken from pitch column cooled in the immersed heat exchanger and delivered to appropriate storage tanks (Fig. 1). No condensation fractions' streams are come in the fractionating column No. 8 (Fig. 1). Ground product of this column is a stripping fraction, which is cooled and delivered in the reflux tank No. 20. A part of this fraction is given for flooding in the pitch column. Naphthalene and phenol fractions are taken off from fractionating column and are cooled in the immersed heat exchanger and are bound for storage tank. Claroline and liquor streams from upper section of fractionating column through coil-in-box condenser are come in the separator.

For the purpose of controlling the quality of bottom products of the columns – the pitch and the stripping fraction – through the barbotagers to the columns ' 7 and ' 8 the superheated steam is added. In order of its production in the convectional chamber of the pipe furnace ' 3 the superheater coiled pipe is installed, to which the middle pressure steam from the shop main is supplied.

Case study
The analysis of the process technological scheme and the schedule of works of pitch section allow to choose cold and hot streams of coal-tar distillation process and to define their heat engineering characteristics which are needed for carrying-out the heat integration. (Table 1).

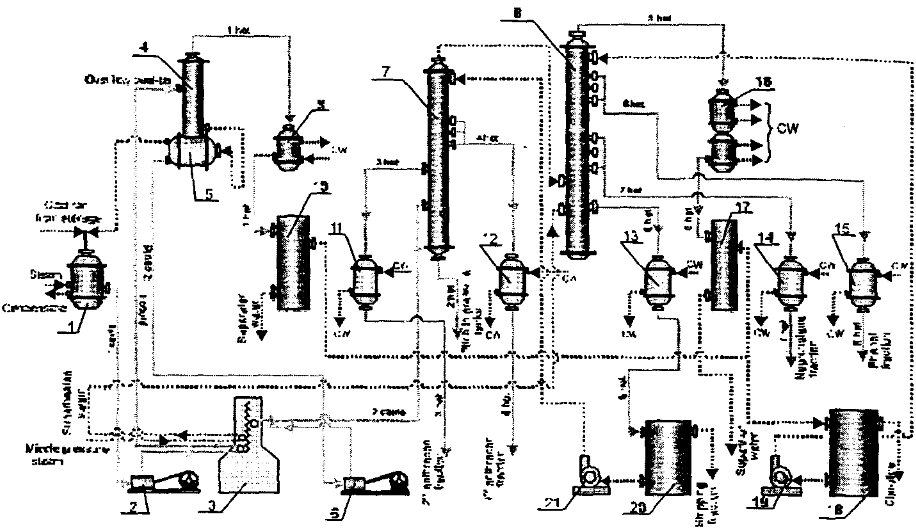

Fig 1. Typical flowsheet of coke-pitch plant

1 - intermediate tank of coal-tar; 2, 6 - three plunger pump; 3 - pipe furnace; 4 - evaporator; 5 - dehydrated coal-tar tank; 7 - pitch column; 8 - fractionating column; 9, 16 - condenser; 10, 17 - separator of claroline; 11 - 15 - immersed condenser; 18, 20 - reflux tank of claroline and stripping fraction; 19, 21 - reflux tank of fractionating and pitch columns.
CW - cooling water.

Table 1. Stream data for flowsheet (Fig. 1)

'	Stream	Type	T_S, K	T_T, K	C, $Jkg^{-1}K^{-1}$	W, kgs^{-1}	ÑÐ, kWK^{-1}	Δ Í, kW
1	Crude coal-tar	Could	345	393	1800	4,6	8,28	397,440
2	Dry coal-tar	Could	387	660	1700	4,28	7,28	1986,348
3	Steam of vaporizer water	Hot	387	313	1108	0,576	6,38	472,100
4	Pitch	Hot	640	553	2000	2,461	4,92	428,200
5	2 anth. Fraction	Hot	605	370	2250	0,3358	0,756	177,554
6	1 anth. Fraction	Hot	580	380	2250	0,7268	1,64	327,060
7	Condensate of fract. column	Hot	390	310	3545	0,044	0,156	12,630
8	Stripping fraction	Hot	500	340	2250	0,437	0,98	157,320
9	Naphthalene fraction	Hot	480	390	2250	0,4508	1,01	91,287
10	Phenol fraction	Hot	450	350	2400	0,138	0,331	33,120
11	Overheating of steam	Hot	413	623	2000	0,11	0,22	46,200

From the grid diagram of the existing heating scheme, which is shown at the Fig. 2, it is seen that it is no recuperation of the heat energy in the concerned plants. Using earlier created software (Tovazhnyansky *et al.*, 1999), which is based on the main principles and the rules of Pinch-Analyses (Smith, 1995; Smith *et al.*, 2000) we will build the composite curves for technological streams presented in the Table 1 (Fig. 3). There are typical composite curves for the non-integrated process. We see that the process using power makes a total ~ 2,43 Ì W, and using power of cold utilities equal ~ 1,7 Ì W and the heat rating available now for recuperation is ~ 1,7 Ì W. At the same time the analyze of the technological streams of plant transport network shows that the pitch steam ' 4 with temperature 553 K pass via pitch main to the pitch store. The pitch main length is under 100 m and it does not have a thermal insulation. Therefore now because of strong dependence the pitch thickness on temperature, its temperature can't be reduced before entering the store. The calculations of flow resistance of pitch main with taking into account the heat transfer with the environment showed that with the pitch main thermal insulation the existing pump will manage with the pitch swap when decreasing the temperature up to 425 K. The overall cost of thermal insulation considering the operation work will come to c_{ins} ~ 2000$. Later on we will consider this value as a constant component when defining the targets of capital costs. It is clear that since c_{ins} in this case don't depend on ΔT_{min} then it won't influence on the ΔT_{min} value on its determination.

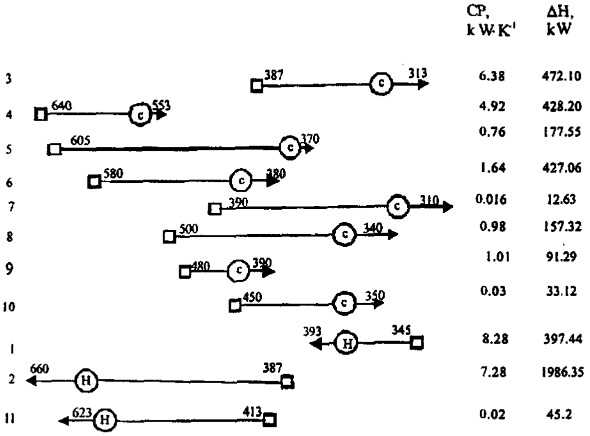

Fig.2. Population of streams for coal-tar distillation unit

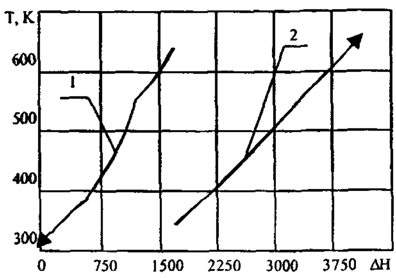

Fig.3. The composite curves for heat network of existing coal-tar distillation unit; 1 – hot composite curve; 2 – could

Streams ' 3 and ' 8 (Table 1) are taken off from the column actually at atmospheric pressure and then are condensed and cooled in the immersed condensers (coolers). The composite curves have been built without taking phase changes into account, i.e. according to their mean streaming heat capacity $CP = \frac{\Delta H}{T_T - T_S}$ (Smith *et al.*, 2000), but it can lead to the error in determination of the driving temperature difference. Therefore we supplied the composite curves technique with the capacity of accounting the phase changes in the technological streams. In the same time the primary coal tar and dehydrated tar are heated under increased pressure and for determination ΔT_{min} we have taken the average values of the stream heat capacities. At this stage of the project the stream ' 11 has to be excluded from the heat integration on the technological reasons. As a result the stream data considering the sectioning of the streams 3, 8 and the exclusion of stream 11, will be considered. The heat transfer coefficients of the streams are determined taking to consideration the using of shell-and-tube heat exchangers.

Let's analyze the influence of accounted phase changes of the streams 3 and 8 on the definition of the targets for the retrofit project. In this connection taking into account the zero recuperation of heat energy at the plant and that the immersed condensers – heat exchangers have already served out and they have to be changed, we will examine the project as a Grassroots Pinch Project.

On analysis the energy saving ability we will use following cost data. The flows in the pipe heater were heated by coke-oven gas. It cost is50 $ US/kW per year. The cooling water cost 7.3 $ US/kW per year. We took the following costs of heat exchangers:

For the corrosion streams No. 9, 10

- 5000 +500 (HT surface area)^{0,95} $ US;

for the rest of the streams:

- 5000 +300 (HT surface area)^{0,87} $ US.

We will define the capital costs in case of 5 years credit with fixed credited rate equal 10%. Note that when determining the capital cost the number of heat exchangers was defined by the minimum value N–1 (Smith, 1995), without sharing at Pinch, where N – overall number of the integrated streams. We won't take into account the heat-transfer area of hot utilities as it already exist in the pipe furnace.

Cost curves for the technological streams with the changed target temperature of stream No. 4 and without accounting the phase changes in streams No. 3, 8 show that ΔT_{min} in this case will come to 32 K (Fig. 4), and the mentioned optimal cost Ï ≈ 65030 $ US.

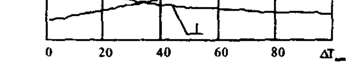

Fig.4. Cost curves for process of coal-tar distillation without taking into account of phase change. 1 – Annual capital cost vs. ΔT_{min}; 1 – annual energy cost vs. ΔT_{min}; 1 – Common annual cost vs. ΔT_{min}.

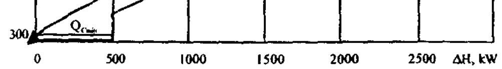

Fig.5. Composite curves for process of coal-tar distillation without taking into account phase changes and ΔT_{min}=32K; 1 – hot composite curves; 2 – could composite curves

At the Fig. 5 are drawn the composite curves for particular approximation and ΔT_{min} = 32 Ê. They demonstrate the localization of the Pinch at 387 K of hot streams. The accounted target for the hot utilities in this case is equal Q_{Hmin} ≈ 538.8 kW+ΔH_{11}, where ΔH_{11} ≈ 46,2 kW – the changing of the stream enthalpy (total heat) of the 11 stream, i.e. Q_{Hmin} ≈ 585 kW, or ≈ 21% of the power using from hot utilities at the present time. The target for the cold utilities will be equal Q_{Cmin} ≈ 495 kW, what makes ≈ 29% of cold utilities usage during the process at the present time. The total heat transfer surface area in present calculation is determined by value A_{tot} ≈ 376.0 m^2, and the surface area of heat exchangers installed for the cold utilities is equal A_{cold} ≈ 24,3 m^2.

The composite curves construction with taking into account the phase changes in the streams 3 and 8 indicates the best value ΔT_{min} = 26 Ê (Fig. 6), and reduced total target cost is equal 64300 $ US, what is less on 730 $ US than when accounting without phase changes. The composite curves constructed in this they decreases the external utilities using power on ~ 400 kW. Total value of the external hot utilities using power for the heat network (Fig. 9) accounts ~ 62% and 48% of the external cold utilities power.

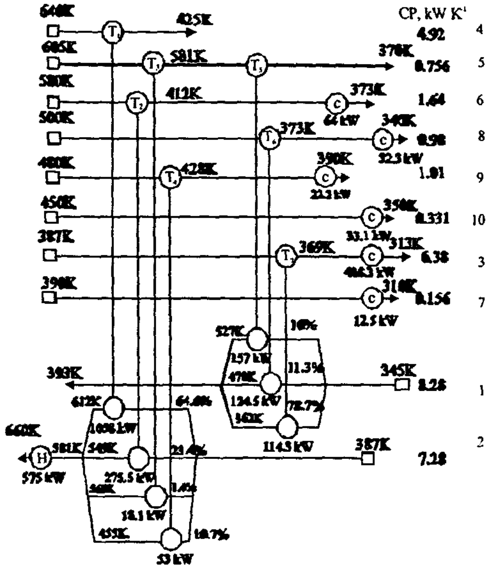

Fig.8. Project of heat network for unit of coal-tar distillation. T – heat exchanger, H – heaters, C – coolers

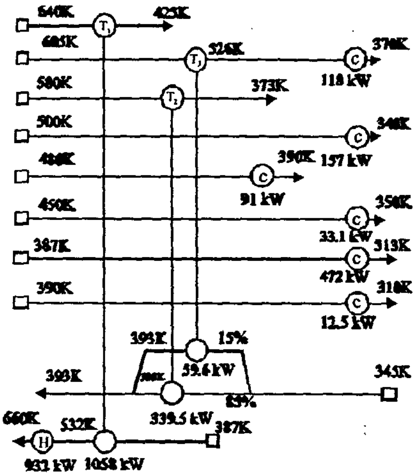

Fig.9. The most profit matches

Conclusion

Using the pinch-analysis technique, the retrofit project for the coal tar distillation plant was suggested. This project let to decrease the external hot utilities usage on 74 % and cold utilities usage on 65 %. And also offered the way of step-by-step retrofit of the plant.

Acknowledgment

This work was performed with European Commission support (Program INCO COPERNICUS IC15 – CT98 –0506 (DG12 – CDPE)) and support of Know-How fund (Program REAP UKR/395/41/0007).

Notation

c – cooler, H – heater, ΔH – change of enthalpy, Q_{Cmin} – requirement for cold utility , Q_{Hmin} – requirement for hot utility

References

Stork W.J., 2001, Energy cost hit earnings hard. *Chemical and Engineering News 5 February, 5.*

Stork W.J., 2001, Chemical Industry is more energy efficient. *Ibidem, 19.*

Tovazhnyansky L.L., Kapustenko P.A., Ulyev L.M., 1999, Determination plant energy saving potential with the help of stream composite construction . *Integrovani Tekhnologii ta Energozberezhennia. No. 1. 14 – 27.*

Smith R., 1995, Chemical Process Design. *McGraw-Hill.*

Smith R. Klemes J., Tovazhnyansky L.L, at al,. 2000, Fundamentals of Heat Process Integration. *Kharkov. NTU "KhPI".*