

## The Choice of the Optimal Retrofit Method for Sections of the Catalytic Reforming Unit

Leonid M. Ulyev<sup>\*a</sup>, Petro O. Kapustenko<sup>a</sup>, Darina D. Nechiporenko<sup>b</sup>

<sup>a</sup>AO "SODRUGESTVO – T" Company, per. Krasnoznamenny, 2 off. 19, 61002 Kharkiv

<sup>b</sup>National Technical University "Kharkiv Polytechnic Institute", 21 Frunze St., 61002 Kharkiv, Ukraine  
[leonid.ulyev@gmail.com](mailto:leonid.ulyev@gmail.com)

Hydrotreating section and catalytic reforming section of catalytic reforming unit L-35-11/600 were examined in this paper. This unit was designed for processing large fraction of naphtha by catalytic reforming in order to obtain components of gasoline with an octane number 78-85 points. Pinch diagnostics for these sections was carried out. Comparative economic analysis of their effectiveness after the proposed retrofit was performed for each section separately and for the total their flowsheet. The implementation of the Pinch Method for hydrotreating section will reduce energy intensity by 2.2 MW. Energy consumption for catalytic reforming section reduced by 6.4 MW. Energy consumption for joint integration of hydrotreating section and catalytic reforming section reduced by 11.4 MW. Therefore, it was concluded that Pinch design for these sections of catalytic reforming unit L-35-11/600 is most advisable to carry out for the two sections together.

### Introduction

Ukrainian oil products market continues to evolve, but its development is constrained by low depth of the refinery of the country, unreasoned fiscal policy and vague legislation in the area of alternative fuels (UAENERGY, 2012). Refining and petrochemicals are energy intensive industries and energy consumption affects to the finished product cost vastly. Increased energy efficiency in processes at existing refineries is an important element of sustainable development for our country. Heat exchanger networks have been a major source of energy savings, but process changes and utility system optimization have also played a part. The use of the Pinch Method allows obtaining substantial financial profit by minimizing of energy consumption by maximizing heat recovery within the considered energy-technological system (Kemp, 2007). The paper presents an industrial case study. The objective of this paper is to analyse the potential of heat integration in two sections of catalytic reforming unit L-35-11/600.

### 1. Process description

This work is done with Pinch diagnostic of Kherson Refinery. Catalytic reforming unit L-35-11/600 was designed for processing large fraction of naphtha by catalytic reforming in order to obtain components of gasoline with an octane number 78-85 points.

This installation consists of three main sections:

- Hydrotreating section
- Catalytic reforming section
- Deethanization and stabilization catalysate section

Feedstock of this unit is naphtha. It goes to the hydrotreating section where hydrotreating reaction takes place on the catalyst in the reactor R-1 in the presence of hydrogen. Then feedstock purified from sulfur compounds sent to the catalytic reforming section to the reactor R-2 in which the aromatization reaction takes place on the catalyst. The project provides for carrying out the process of catalytic reforming in three steps. Mixture of gas and feedstock consistently goes to the reactors R-2,3,4/1,2 and after cooling it is fed to deethanization and stabilization catalysate section.

In order to perform Pinch design of the entire unit, it is necessary to carry out Pinch diagnostic and perform Pinch design for each section of this unit separately (Jannelli E., 2013).

In this paper, hydrotreating section and catalytic reforming section of catalytic reforming unit L-35-11/600 were examined. Flowchart of these sections is shown in Figure 1. Pinch diagnostic for these sections was carried out (Smith et al., 2012).

The analysis of the scheme showed significant energy saving potential which is contained both in elementary heat loss to the environment and in irrational technology of heat transfer between process streams.

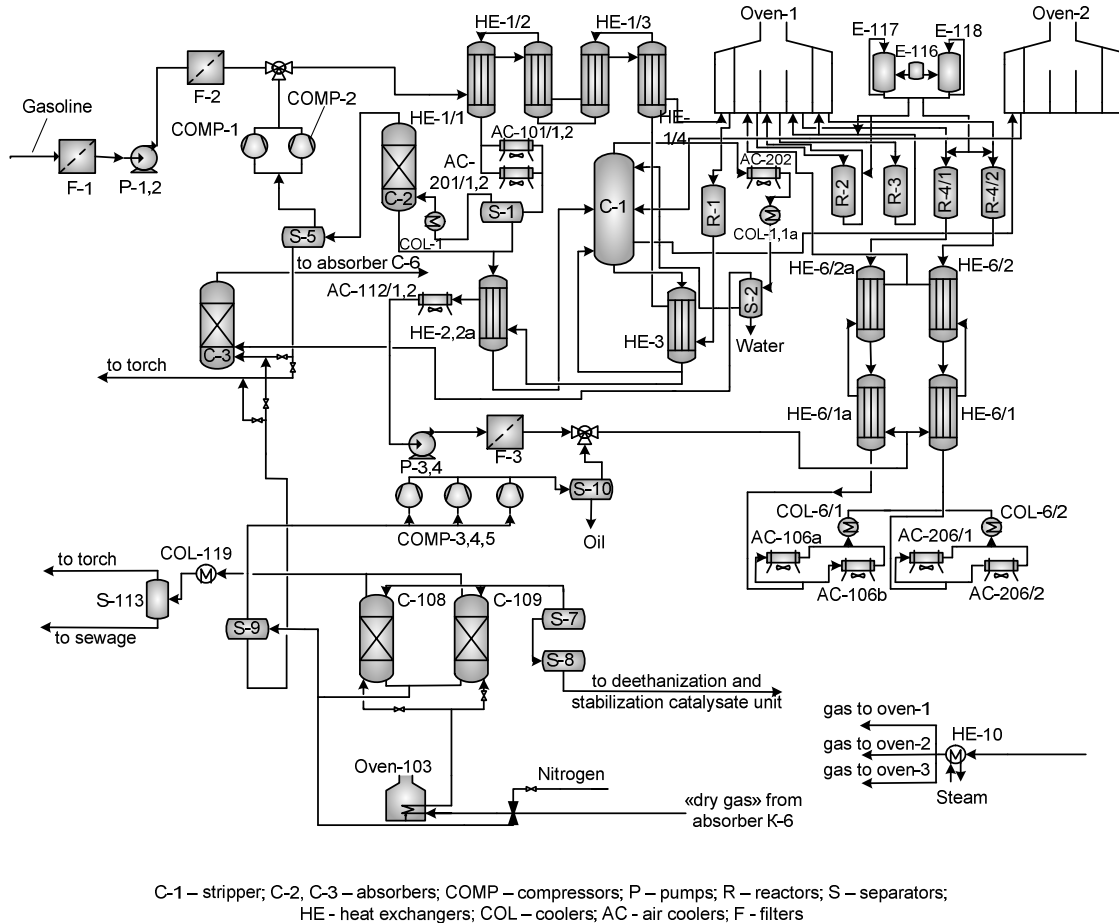


Figure 1: Flowchart of existing process

## 2. Process data extraction

For the implementation of Pinch Analysis process must have all the data on existing energy consumption of the process (Klemes, 2013). Plesu et al. (2001) have provided an example from the petro-chemical industry. Technological process data of hydrotreating and catalytic reforming were taken from a real unit. During the examination of the catalytic reforming unit L-35-11/600 the main parameters of the process streams that may be included in the integration were determined.

Grid Diagram (Linnhoff and Flower, 1978) was constructed on the basis of these data, heat exchange between process streams was determined (Figure 2).

The rate of heat recovery of the hydrotreating section and catalytic reforming section was calculated. It is equal to 12 MW for hydrotreating section, 21 MW for catalytic reforming section and 32 MW for both these sections. Composite Curves for the existing process have been built using obtained technological process data of hydrotreating and catalytic reforming (Figure 3).

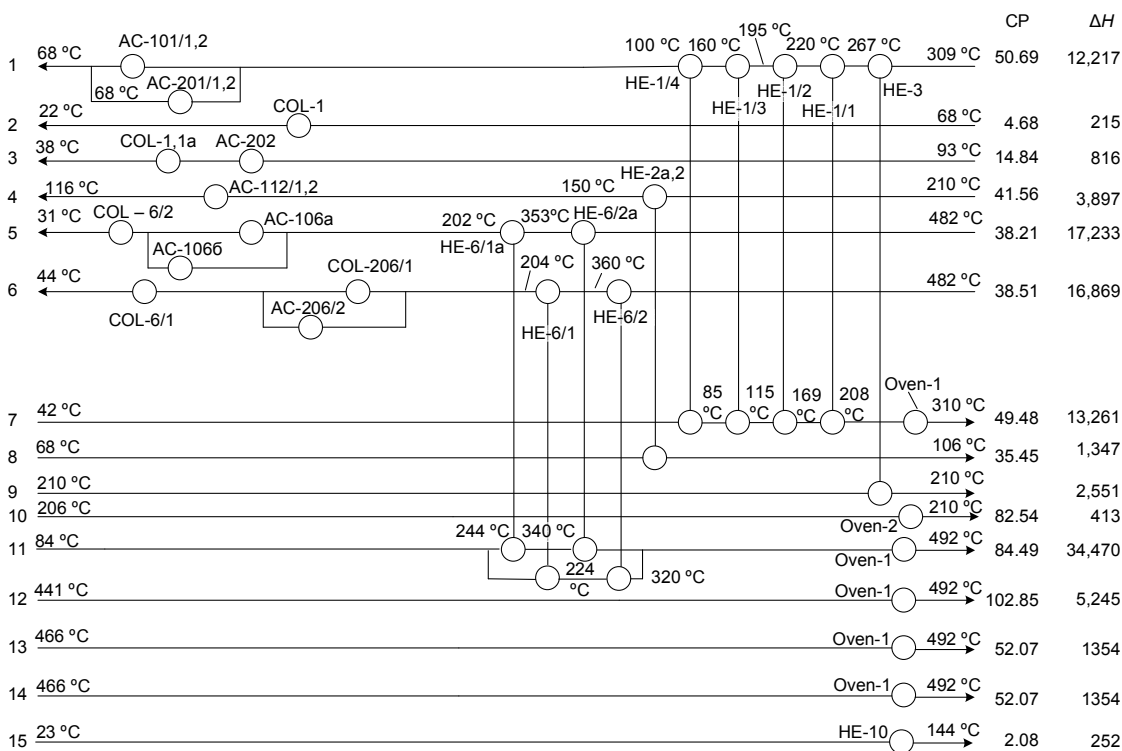


Figure 2: Grid diagram of existing process

Reduction of the minimum temperature difference between the heat carriers in the heat exchangers ( $\Delta T_{min}$ ) is necessary to reduce the energy consumption in the chemical-process system. Reduced energy consumption can be done by creating a project of retrofit of the process heat exchange system for economically optimal value of  $\Delta T_{min}$  which is determined from the trade-off between competitive values of energy cost and the cost of heat transfer surface area (Feng et al., 2011).

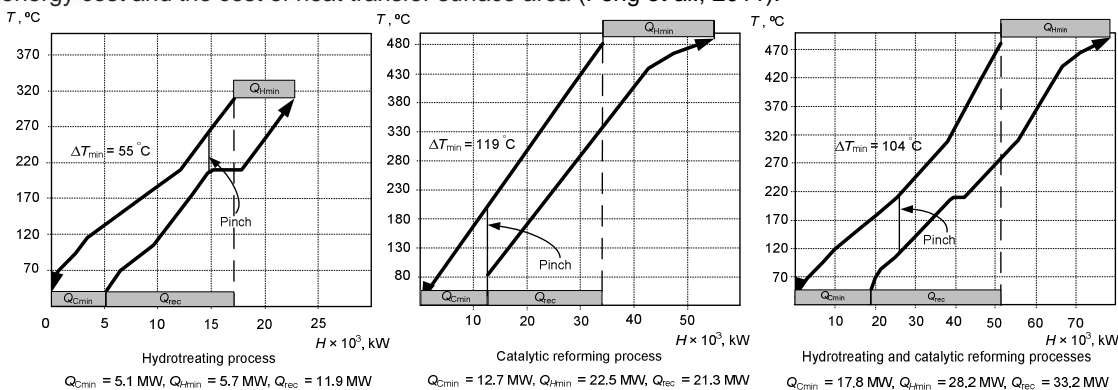


Figure 3: Composite Curves of the existing process

### 3. Heat energy integration

The most economically important values that materially affect the present value of the project has to be determined in order to economically optimal integration process (Al-Mutairi Eid, 2010). The cost of the hot utilities used in the process is assumed to be 400 USD/(kW·y) assuming 8,000 h/y activity.

Necessary capital investment and payback period can be assessed before the project using the price of heat transfer equipment, provided by the manufacturer. Capital cost of the heat exchanger can be defined by Eq(1):

$$\text{Capital cost} = A_T + B_T (S)^C \tag{1}$$

where:  $A_T = 40,000$  USD – the cost of installing a heat exchanger;  $B_T$  – rate equivalent to the cost of 1  $m^2$  surface area of heat transfer, for shell and tube heat exchangers  $B_T = 500$ ;  $S$  – heat exchange surface area of heat exchanger;  $C$  – factor reflecting the non-linear dependence on the value of the cost of the heat exchanger to the heat transfer surface,  $C = 0.87$ .

Calculation of the present value cost of the project allows determining the minimum value of the temperature difference between the heat carrier in the future heat recovery system considering the current heat exchangers (Figure 4).

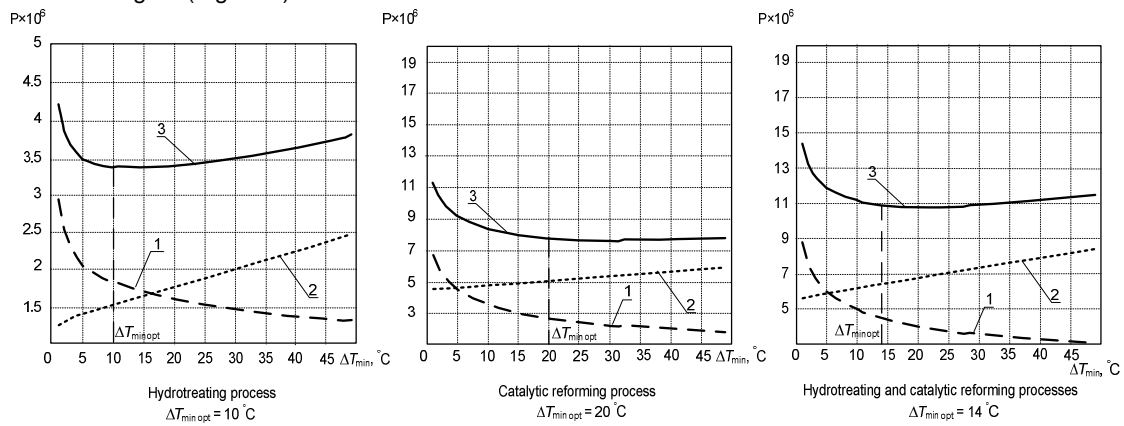


Figure 4: The dependence of the present value of  $\Delta T_{min}$ . 1 – capital cost, 2 – energy cost, 3 – total cost

For the hydrotreating process this value should be  $\Delta T_{min} = 10$  °C. For the catalytic reforming section this value should be  $\Delta T_{min} = 20$  °C. And for joint project of these processes the optimal value is  $\Delta T_{min} = 14$  °C. The obtained values provide to determine possible energy saving potential of this reconstruction project (Nordman, 2005). Composite Curves can be used for determining target values of external utilities. New Composite Curves of hydrotreating and catalytic reforming processes with an optimised temperature difference were constructed (Figure 5).

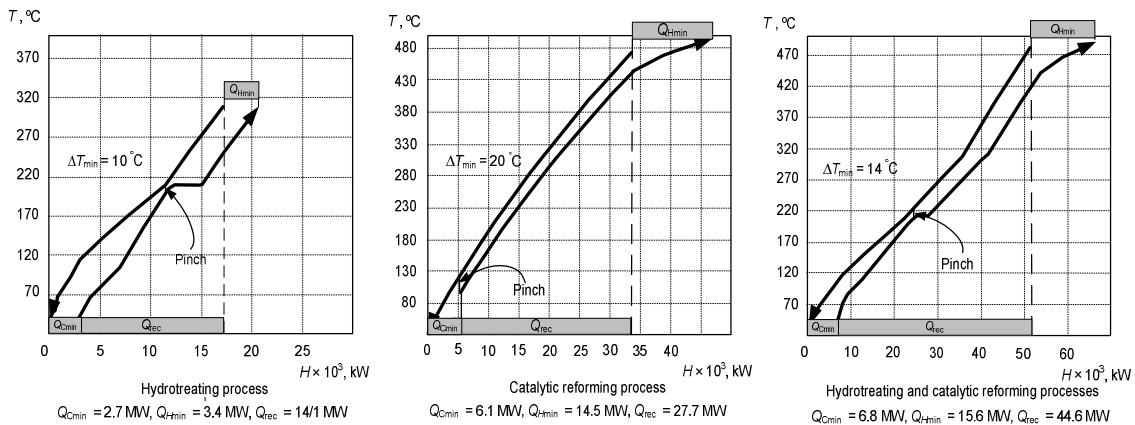
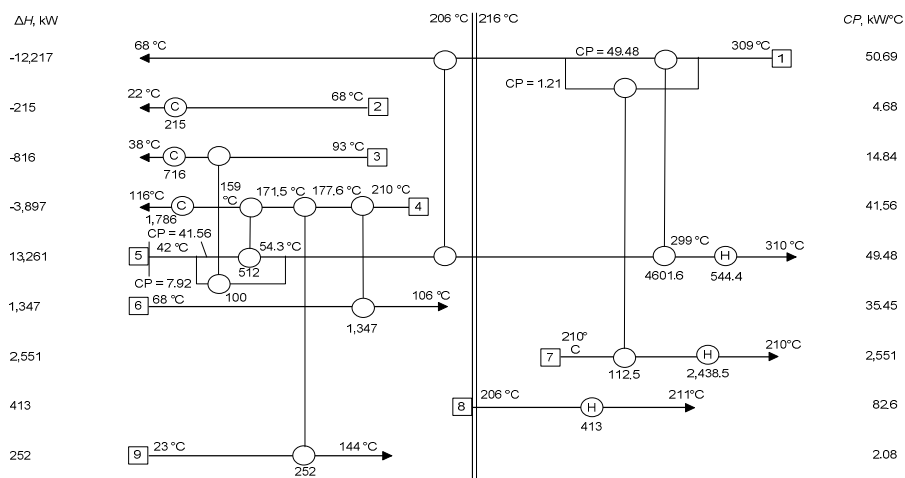
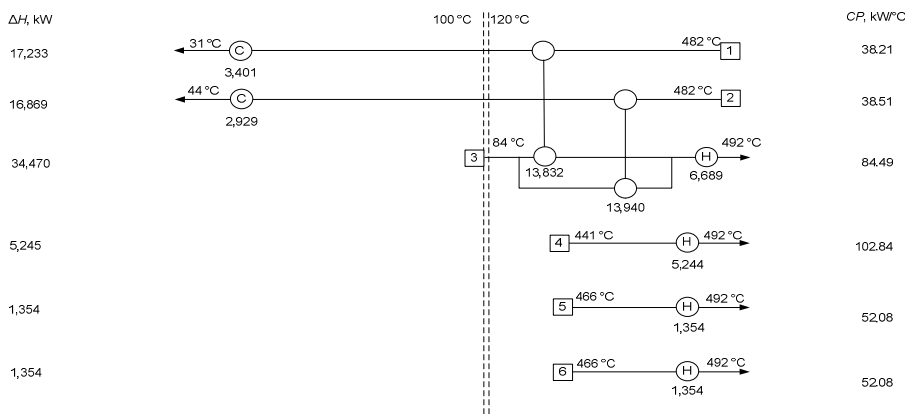


Figure 5: Composite Curves of the integrated process

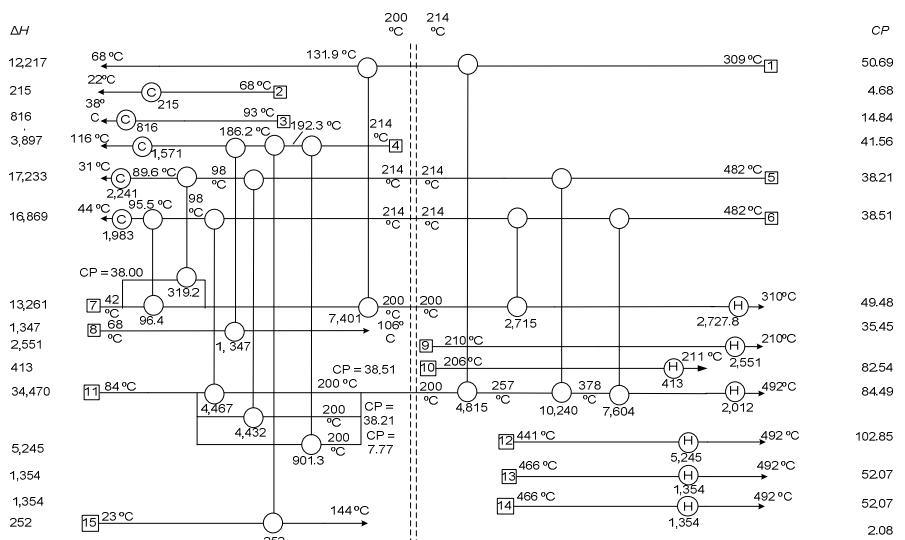
According to the principles of Pinch Analysis (Smith et al., 2000) the new Grid diagrams for the new  $\Delta T_{min}$  value and the capacity of heat-exchange equipment was calculated (Figure 6). Pinch is a vertical line separating Grid diagram into two parts.



Grid Diagram of integrated hydrotreating process



Grid Diagram of integrated catalytic reforming process



Grid Diagram of integrated hydrotreating and catalytic reforming processes

Figure 6: Grid Diagram of integrated processes

Transition to the joint Grid diagram for these sections of the unit by simply connecting of hydrotreating and catalytic reforming processes Grid diagrams is impossible. It is necessary either carry out modernisation for each block separately or in common. In preliminary estimates, upgrading hydrotreating and catalytic reforming sections in common is more economically feasible.

### 3. Conclusions

Pinch diagnostics for hydrotreating section and catalytic reforming section of catalytic reforming unit L-35-11/600 was carried out. Comparative economic analysis of their effectiveness after the proposed retrofit was performed for each section individually and for the total flowsheet.

The implementation of the Pinch design allows to reduce power consumption for hydrotreating process by 2.2 MW. This project allows to decrease the external hot utilities usage by 43 % and cold utilities usage by 47 %. For the catalytic reforming section power consumption is reduced by 6.4 MW. This project allows to decrease the external hot utilities usage by 35.5 % and cold utilities usage by 51.9 %. Energy consumption for joint integration of hydrotreating section and catalytic reforming section reduced by 11.4 MW. This project allows to decrease the external hot utilities usage by 44.7 % and cold utilities usage by 61.8 %.

Therefore, it was concluded that Pinch design for these sections of catalytic reforming unit L-35-11/600 is most advisable to carry out for the two sections together.

Further development of this work assumes the integration of all unit sections and proposals for the implementation of retrofit project.

### Nomenclature

$\Delta H$  – change in flow enthalpy (kW);  $CP$  – heat capacity flowrate (kW/°C);  $\Delta T_{\min}$  – minimum allowed temperature difference (°C);  $Q_{C\min}$  – minimum feasible cold utility (kW);  $Q_{H\min}$  – minimum feasible hot utility (kW);  $Q_{\text{Rec}}$  – the value of energy recovery in the heat exchange network (kW)

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