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Improve of Energy Efficiency a Tool for Reduction of CO_2 Emission

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The most economical method to reduce the CO_2 emission is to avoid its generation. This paper summarizes the results of the work being made in the MOL Group to decrease the green house gases emissions with improving the energy efficiency of process units. Results of heat exchanger network analysis being carried out in different units were presented. Realization of suggested modifications results total 27.2 kt CO_2/year emission reduction and fuel efficiency improvement of 596.5×10^3 GJ/yr. Results of studies for improving the separation/energy efficiency and determination of optimal feed tray location of columns were demonstrated, too. These contribute to decreasing the CO_2 emission with 6.6 kt/year and improving the fuel efficiency with 111.2×10^3 GJ/year. Results of investigation of furnaces were also introduced. Presented modifications results decrease of CO_2 emission of 17.7 kt/year and saving in energy of 252×10^3 GJ/yr. The presented results shows MOL Group is committed to reducing CO_2 emission and improving energy efficiency in both Danube and Slovnaft refineries.

1. Introduction

Emission of greenhouse gases, especially carbon dioxide, is continuously increasing all over the World. On the basis of data of International Energy Agency the CO_2 emission increased from 15 640 million tons/year level in 1973 to 28 003 million tons/year level in 2006, respectively (IEA Report, 2008). As a well known, fact the higher the CO_2 concentration in the atmosphere is higher the global temperature, too. The fear from global warming has led to legislative actions to decrease the carbon dioxide emission, especially in the European Union. Actions those can be made in the refining industry to contribute the reduction in CO_2 emission are the following.

1. Use of alternative energy sources as well as fuel blending components being produced on renewable basis (Holmgren et al., 2007).
2. Improve of energy efficiency of existing processes. Additionally, reduction in the quantity of used energy sources (e.g. natural gas, fuel gas and fuel oil) decreases in the operation cost of a refinery, too (Turton, 2003).

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3. Application of some kind of CO_2 capture technologies to extract CO_2 from the refinery flue gases (Parkinson, 2008).

The aim of this paper is to present the results of studies being made by Downstream Development Process Engineering to improve energy utilization for the Danube Refinery as well as Slovnaft Refinery, too. Results of these studies can be arbitrarily divided into two main areas. One of them is the revision of heat exchanger network of process units applying the so called "pinch" technique, the second one is the collection of other solutions those results more efficient energy utilization.

2. Methodology

The following steps were carried out during the studies. First, an adequate simulation model of process units was prepared on data of test runs being done with close cooperation with professionals of refinery. Our department applies the following engineering tools for modeling: PRO II, Hysys. After validating the model on the base of heat and material balances SuperTarget and Hextran software are used for analyzing the heat exchanger network for improving the energy efficiency. If result of the study suggests to implement new heat exchanger Hextran and STX/Hysys are applied for design it. Afterwards, the original model is changed and the applicability of the suggested solution is checked with rigorous modeling.

The next phase of the study is the cost/benefit analysis. If it gives positive result the modification is implemented. Finally, calculated energy saving is checked with test run.

3. Results and discussion

3.1 Heat exchanger network analysis

Our department systematically investigated the most energy intensive process units to work out solutions for increasing their energy efficiency both in Danube Refinery and Slovnaft Refinery. These studies were prepared by applying the heat exchanger network analysis technique (so called pinch analysis) (Kemp, 2007). Main steps of the study are introduced through the analysis of crude oil preheating train of Atmospheric/vacuum distillation unit 3 (AV-3).

After preparing the simulation model of AV-3 unit based on a test run the heat exchanger network (HEN) was transferred into the SuperTarget program for further analysis. Figure 1 and 2 shows the composite curves and grid diagram of the HEN, respectively.

Composite curves show that considerable energy can be saved with shifting the curves. Grid diagram of HEN also displayed that some exchangers transfer heat across the pinch resulting excess fuel consumption. Calculation showed that the hot energy consumption would be 92.8 GJ/hr in maximum energy recovery case while this value was 121.6 GJ/hr for the base case indicating 28.8 GJ/hr energy saving potential. However, results also showed to exploit this potential the number of heat exchanger units should have been doubled and implementation of more than 1100 m^2 extra surface is required. However, one of our objects was to find solution on minimal capital expenditure basis.

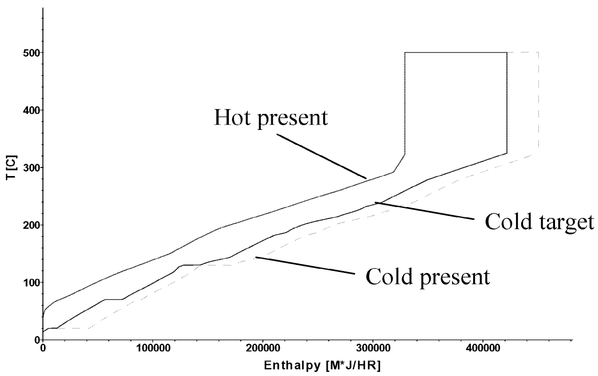

Figure 1 Composite curves of heat exchanger network of AV-3 unit

Additionally, some operational issues had to be viewed, too, e.g. maximum inlet temperature of crude oil into the desalter, maximum inlet temperature of crude oil into the preflash tower, storage temperature of products and set temperature of circulation reflux streams.

During the test run and preparing the model we noticed that some exchangers were severally bypassed. So, the first step was to maximize the load of these units meanwhile we had to minor changes in other parts of the HEN to restore the required temperatures. These covered the following: implementation a new heat exchanger of 300 m^2 area and a new boiler of 6.34 GJ/hr steam production and transpose the crude oil contact order of Light Gasoil and Atmospheric circulation reflux streams. These modifications were adapted into the simulation model and checked their viability. Comparing energy efficiency of modified HEN to the base case we noticed 12.9 GJ/hr saving in fuel. Result showed almost 50% of the maximum possible energy recovery was achieved with this low capital intensive solution. Reduction in the fuel consumption contributes to decrease in CO_2 emission of 6.1 kt/yr.

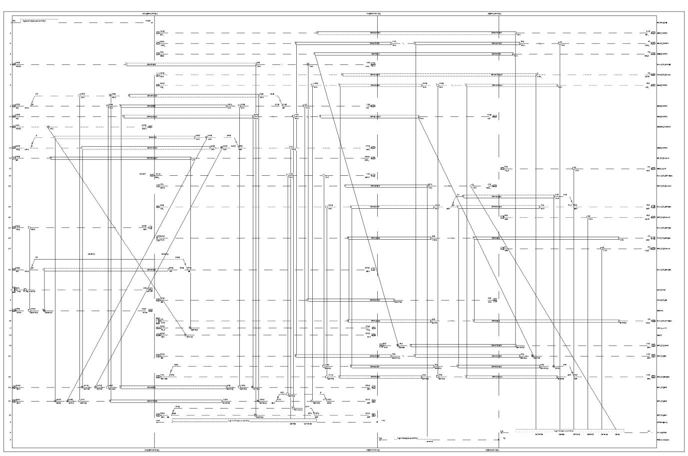

Figure 2 Grid diagram of heat exchanger network of AV-3 unit

Table 1 Results of HEN analysis of different units

Danube Refinery			Slovnaft Refinery		
Unit	CO_2 reduction, kt/yr	Energy reduction, GJ/yr	Unit	CO_2 reduction, kt/yr	Energy reduction, GJ/yr
AV-1	3.0	95.5×10^3	AVD-6	7.7	197.4×10^3
AV-3	6.1	108.4×10^3	AD-5	1.8	27.2×10^3
SDEW	3.0	67.7×10^3	ISOM	0.6	8.0×10^3
LUB	3.7	69.6×10^3	K-HDT	1.3	22.4×10^3

Table 1 summarizes the results of HEN analysis of process units where considerable energy efficiency improvement was accomplished. Namely, Atmospheric/vacuum distillation unit 1 (AV-1), Atmospheric/vacuum distillation unit 3 (AV-3), Lube oil refining unit (LUB) and Solvent dewaxing unit (SDEW) in the Danube Refinery, and Atmospheric/vacuum distillation unit 6 (AVD-6), Atmospheric distillation unit 5 (AD-5), Light naphtha isomerization unit (ISOM) and Kerosene hydrotreater (K-HDT) in the Slovnaft Refinery.

3.2 Other energy saving studies

As mentioned before beside the heat exchanger network revision we investigated other solutions those results reduction in energy consumption, too. Some examples are summarized in the following without the completeness.

3.2.1. Investigation of distillation towers

Distillation systems are energy and power intensive processes and contribute significantly to greenhouse gases emissions. Given that distillation processes account for approximately 5 percent of total energy consumption in the world, it is logical that the industry seeks continuous improvements to the system. Our team investigated many distillation units both in Danube and in Slovnaft refineries to find solutions for their energy improvement.

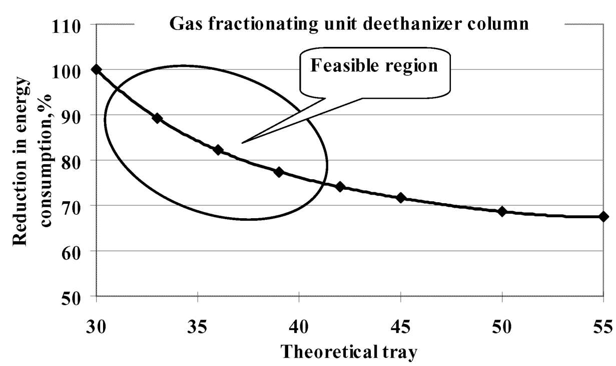

Figure 3 Effect of increase in number of theoretical stages on the energy efficiency

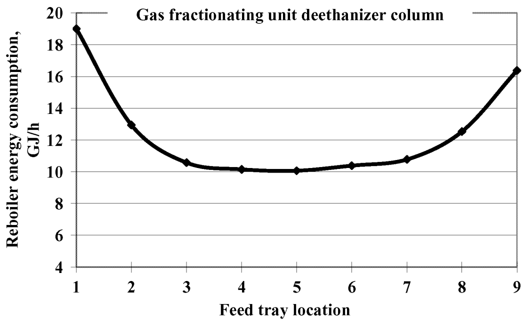

Figure 4 Effect of feed tray location on the energy efficiency

One of the possible solutions to improve energy efficiency for an existing tower is to increase the number of theoretical trays resulting lower reflux and reboiler heat. Figure 3 shows the change of energy consumption of deethanizer column in function of theoretical trays. We highlighted the feasible region where increase in the number of theoretical trays resulted considerable reduction in energy consumption. Technical solution of increase of theoretical trays in a given volume can be increase the tray numbers with decreasing the tray spacing and/or use high efficiency trays.
As Figure 4 displays location of feed tray influences the energy consumption of a distillation tower, too. The example of deethanizer unit shows varying feed tray location resulting almost 50% variation in the reboiler heat. Application of modern process engineering tools makes easy to find the optimal feed tray location e.g. Pro II (Invensys) flow sheet optimizer.
We investigated many columns of different process units both in the Danube and Slovnaft refineries. Table 2 displays the achievable CO_2 emission reduction and improvement in energy efficiency can be accomplished by applying our suggestions
Reduction of head pressure of vacuum column results lower flash zone and furnace outlet pressure, too. Accordingly, lower temperature is required to achieve same evaporation ratio of feed resulting less fuel consumption in the vacuum furnace.

Table 2 Results of investigation of distillation columns

Unit	Potential CO_2 reduction, $ktCO_2$/year	Potential energy saving, GJ/year
Danube Refinery		
Aromatic unit (1 column)	1.5	28.0×10^3
Gas fractionating unit (2 columns)	1.9	24.8×10^3
Ligh naphtha isomerization (1 column)	0.3	17.6×10^3
Slovnaft Refinery		
Reformat Redistillation (2 columns)	2.0	31.0×10^3
Alkylation (2 columns)	0.9	9.8×10^3

Results of study showed by increasing in area of condensator of AV-2 unit vacuum tower the head pressure can be reduced with 25%. This modification contributes to 21.7×10^3 GJ/yr fuel saving that is equal to 1.6 kt/year CO_2 emission reduction.

3.2.2. Investigation of furnaces

The highest energy consumer equipments of a distillation plant are the furnaces. Accordingly, we studied the furnaces of atmospheric/vacuum distillation units in the Danube Refinery to determine whether there is any possibility to reduce their fuel consumption.

One of the possible solutions to increase in efficiency of furnaces is preheating of the combustion air. The prerequisite of this solution is the forced combustion air supply to the burners. From this aspect the investigation of furnaces of AV-3 unit was covered. Increase in temperature of combustion air results higher NO_x emissions. From this reason the temperature of air-preheating was limited to 100°C during the study, where the increase in the NO_x emission is not significant. Another limit was the acid dew point of the flue gas. We calculated of this value on the basis of composition of exhaust gases. Considering the abovementioned limits the results of the investigation showed that approximately 4.5 kt CO_2/yr emission reduction can be achieved and 67×10^3 GJ/yr of energy can be saved.

We investigated the furnaces of the other distillation unit (AV-2), too. Three atmospheric furnaces are in this unit, one of them having higher capacity than that of other ones but it did not contain steam super heating coils. Accordingly, all furnaces should be operated with relatively low capacity resulting higher energy consumption than that would be optimal. So, implementation of steam super heating coils into the higher capacity furnace was investigated applying FRNC 5 software. Results showed that the reconstruction of the furnace could be solved by minor changes, namely two pairs of coils of convective zone switched to steam superheating. On the basis of the calculation it was assessed that these modifications cause negligible effect on other parts of the furnace and outlet temperature of crude oil would not change significantly. After implementing the steam super heating coils one of the smaller capacity furnaces can be stopped meantime the load of working furnaces can be maximised. This results 63 GJ/kt(crude) saving in the fuel consumption and 4.5 tCO_2/kt(crude) emission reduction.

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