ENERGY RETROFIT WITH SIMULTANEOUS ENERGY OPTIMIZATION FOR A CRUDE FRACTIONATION UNIT

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Abstract

This paper presents the results obtained in the energy retrofit of a Crude Topping Unit. CRUDOPT, an optimization procedure that combines changes in operating conditions and pinch analysis to explore energy retrofit alternatives, was used. Five basic savings horizons were obtained for different crude types. In the first stage of the application of CRUDOPT, a potential savings horizon (maximum possible savings) of approximately $1.5 millions per year was identified. A subsequent economic analysis identified one retrofit opportunity were the savings are around $0.7 million (47% of horizon) with a payout of 1.2 years. Finally, additional savings were also identified when the reallocation of pumparounds returns is considered. These savings bring down the payout period to 1.1 years. Over a five years horizon, the net revenue (total savings over 5 years - capital expenditure) are of the order of $3.2 millons.

Introduction

In many cases, crude fractionation units are retrofitted for the purpose of increasing throughput. Since the crude fractionation process is energy intensive, another goal consist of retrofitting the pre-heating train so that maximum energy efficiency is achieved. When the former is performed, the latter can be included in a synergistic manner. In addition, it is standard practice to process different types of crude at different times of the year. This adds another dimension to the retrofit problem, in which a unique preheating train and eventually column modifications are introduced for the purpose of satisfying different mixtures of crudes being processed at the maximum energy efficiency possible in each case.

CRUDOPT

The retrofit procedure is carried out in several sequential steps.

1) **Simulation of the existing unit:** The purpose of this step is to determine the quality and quantity of products and several parameters (temperatures, heat exchangers duties, etc).

2) **Flowsheet simplification:** This step consists of replacing the current heat exchanger network (HEN) by one-side heaters and coolers. These new units have the solely purpose of accounting for the required duties to meet final stream temperatures.

3) **Determination of the basic savings horizons:** This step consists of performing a pinch analysis of the aforementioned simplified network, followed by an optimization. The optimization targets maximum energy recovery by varying operating conditions (temperatures, pump-around rates, steam injection rates, etc). The analysis is done for each of the crudes to be fed to the unit. This will lead to different horizons for each case. In all cases, the optimization is carried out under the constraints of constant product quality.

4) **Synthesis of the horizon networks:** Using pinch design methodology, a realizing network for each crude horizon is constructed. These horizon networks constitute grass-root designs, which could greatly differ from the existing HEN.

5) **Proposition of a retrofit network:** A comparison of the existing network with the basic horizon networks is conducted. Common patterns are established to propose a retrofit network. The following diagram summarizes the nature of the retrofit. Horizon networks are too expensive and their payout period is too long. Therefore, less expensive networks are sought so that the capital expenditure is limited and the payout period is reasonable.

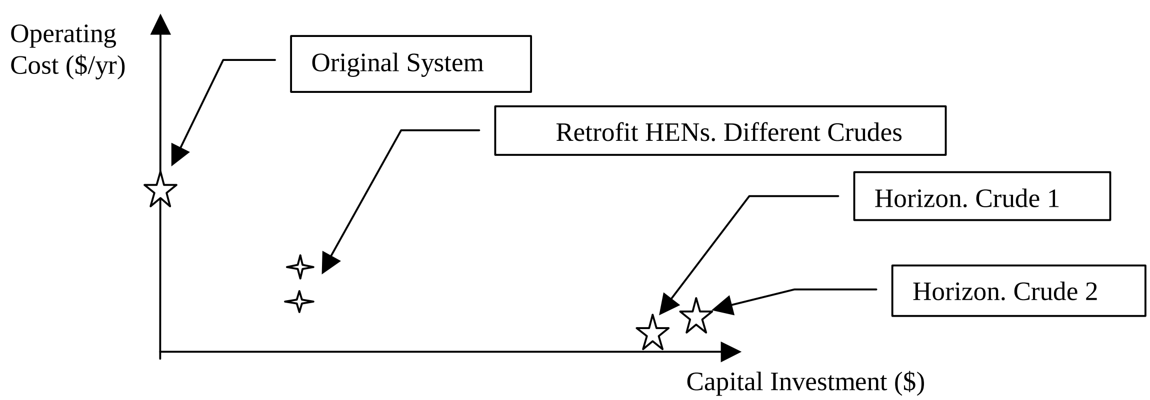

Figure 1

6) **Test of feasibility the new retrofit network:** In this step the changes are implemented in the existing network. Simulations with the different crude mixtures are conducted to evaluate the flexibility of the network. Also feasibility of in situ implementation is tested.

7) **Cost analysis:** An estimation of operating and capital cost to determine the pay-out of the project is conducted.

RESULTS AND DISCUSSION

The case study consists of an atmospheric unit processing mixtures of different types of crude. The crude blend selection is made based on financial and seasonal reasons. Three basic crudes, named as CR1, CR2 and CR3 are used for blending.

Simulation of the Present Plant:

The simplified flowsheet of the unit was simulated using each of the crudes. *This simplified flowsheet was used to mimic current conditions.* The optimization procedure was then run for the three types of crude. While doing this optimization the products quality was maintained constant. Variables varied are pumparound duty, main fractionator inlet temperature and steam flowrates.

Savings Horizons

Five horizons were simulated. They were obtained using CR1, CR2 and CR3 crudes. Two sets of specifications for CR1 (original and modified) gave rise to two horizons. Similarly, CR2 was run using two sets of specs. The utility consumption of the present HEN is compared with its horizon, and the horizon that is obtained after optimization is accomplished.

Table 1: Energy Consumption (10^6 Btu/hr)

Type of Crude	**Base Case**		**Optimized Case**
	Current HEN	*Horizon*	*Horizon*
CR1 (Original Specs)	135.9	75.73	70.25
CR1 (New Specs)	*N/A*	*N/A*	67.75
CR2 (Original Specs)	*N/A*	72.34	63.79
CR2 (New Specs)	*N/A*	*N/A*	75.05
CR3 (Original Specs)	*N/A*	74.82	47.73

Roughly, the savings are of the order of 65 MMBtu/hr, equivalent to approximately $1.5 million/year ($2.15 /MMBTU, 80% furnace efficiency and 8700 hrs/yr were used). This value is only based on the simulation of CR1 for which the current energy consumption is known. This optimum horizon was obtained exploring variables such that the target products would not differ in quality and/or quantity. Using these data five heat exchanger networks representing the horizon savings were designed. As these networks establish a *horizon* of retrofit, but not a *goal,* they are only used as starting point to perform the retrofit studies.

Retrofit Network

The retrofit network was obtained by the addition of five new exchangers and the relocation of two existing exchangers. Original and final networks are shown in Figure 2 and 3 respectively.

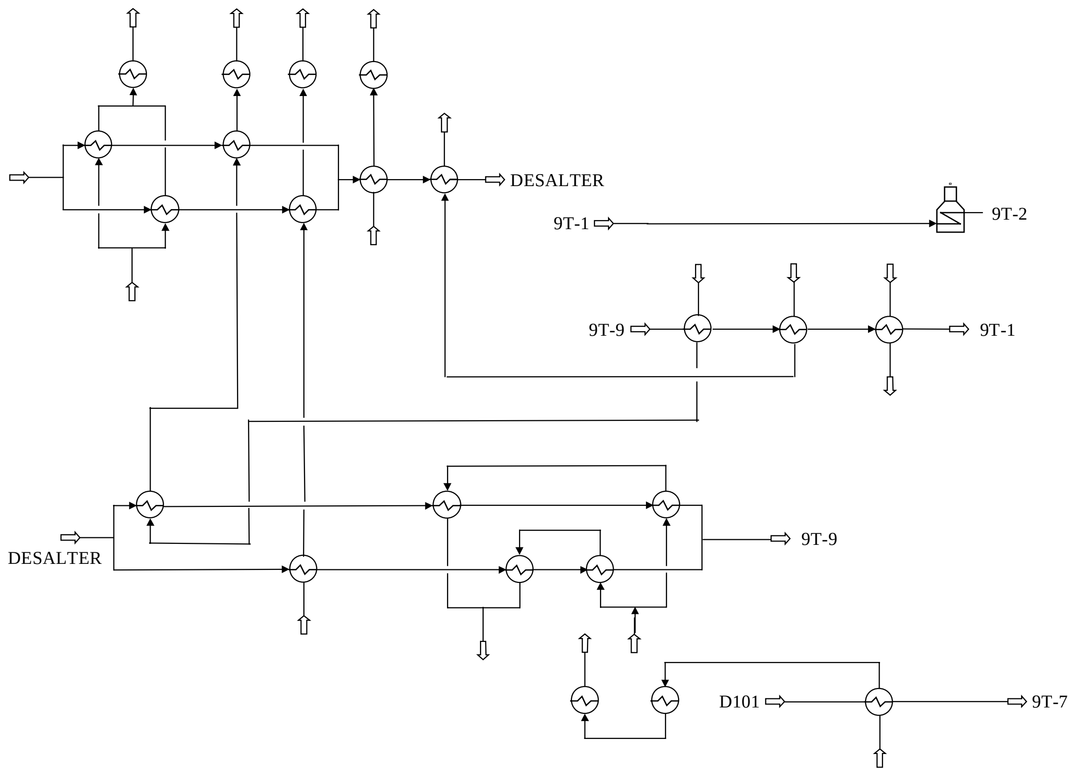

Figure 2: Existing HEN

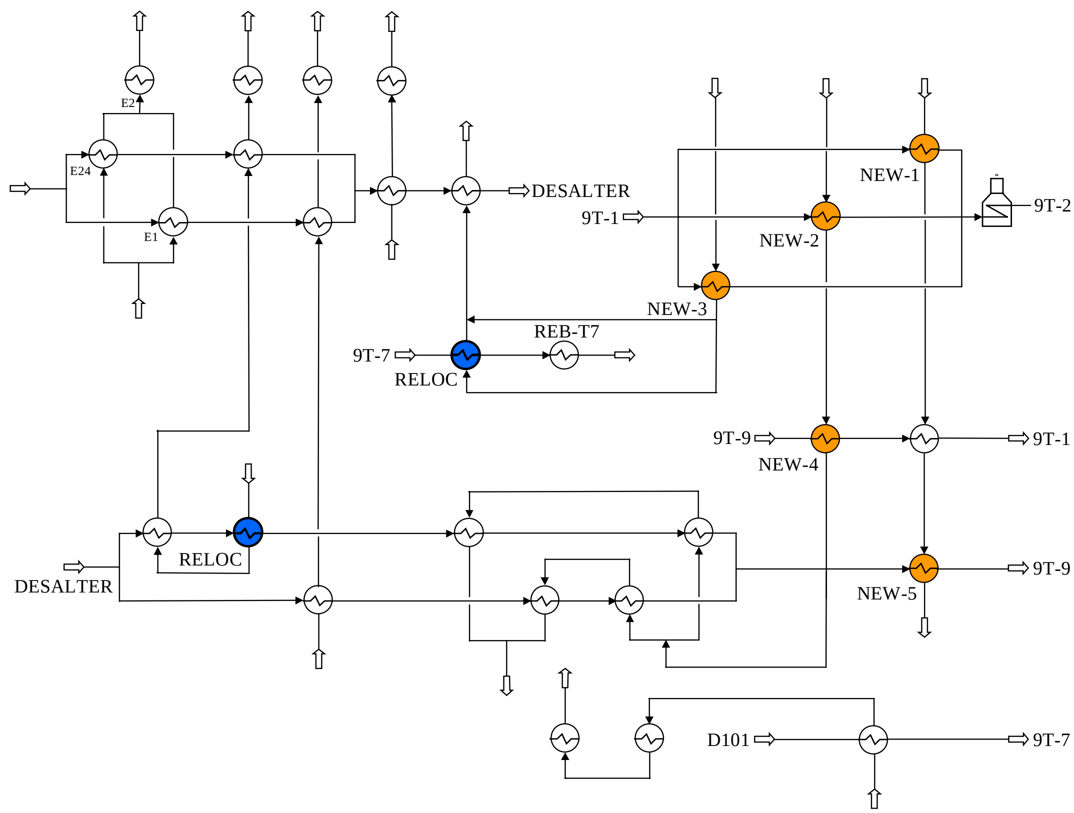

Figure 3: Retrofit HEN

Simulation of New Retrofit Network

To check the flexibility of the new retrofit network, CR2 crude was introduced in the simulations. Starting with pure CR2 crude, cases with increasing amounts of CR1 were simulated. The furnace heat load is considerably lower than in the case of CR1 crude.

Table 2: Energy consumption (10^6 Btu/hr.)

CRUDE	Base Case	Horizon	Retrofit case
100% CR1	132.47	75.73	107.27
80% CR2, 20% CR1	*N/A*	*N/A*	101.34
90% CR2, 10% CR1	*N/A*	*N/A*	100.22
100% CR2	*N/A*	72.34	98.12

Column Changes

To explore if extra savings can be expected making changes in the pumparound of the main column, a heat supply demand diagram for the unit was constructed (Figure 4). This diagram overlaps the supply and demand of heat. The demand in this case is only the crude stream. Any supply that exceeds the demand at any given temperature can only be used to satisfy demand at lower temperatures (left).

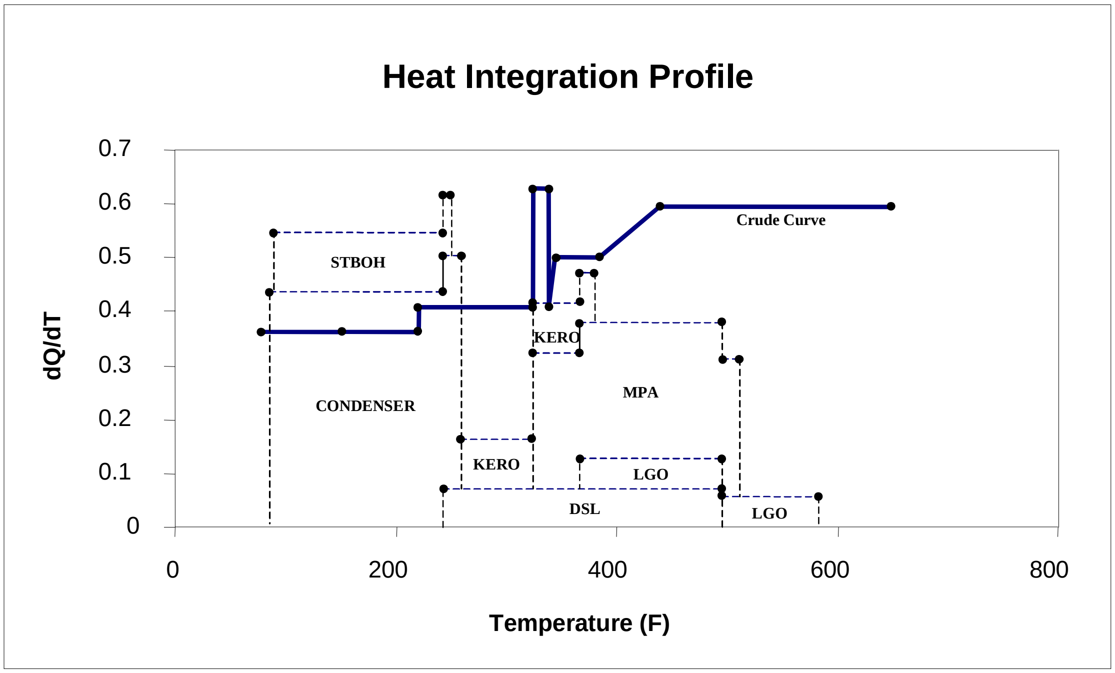

Figure 4

In exploring this diagram, one discovers that there is a large supply surplus in the condenser of the atmospheric main column. This supply can only be used if it is transferred to the pumparound (Figure 5) across the pinch.

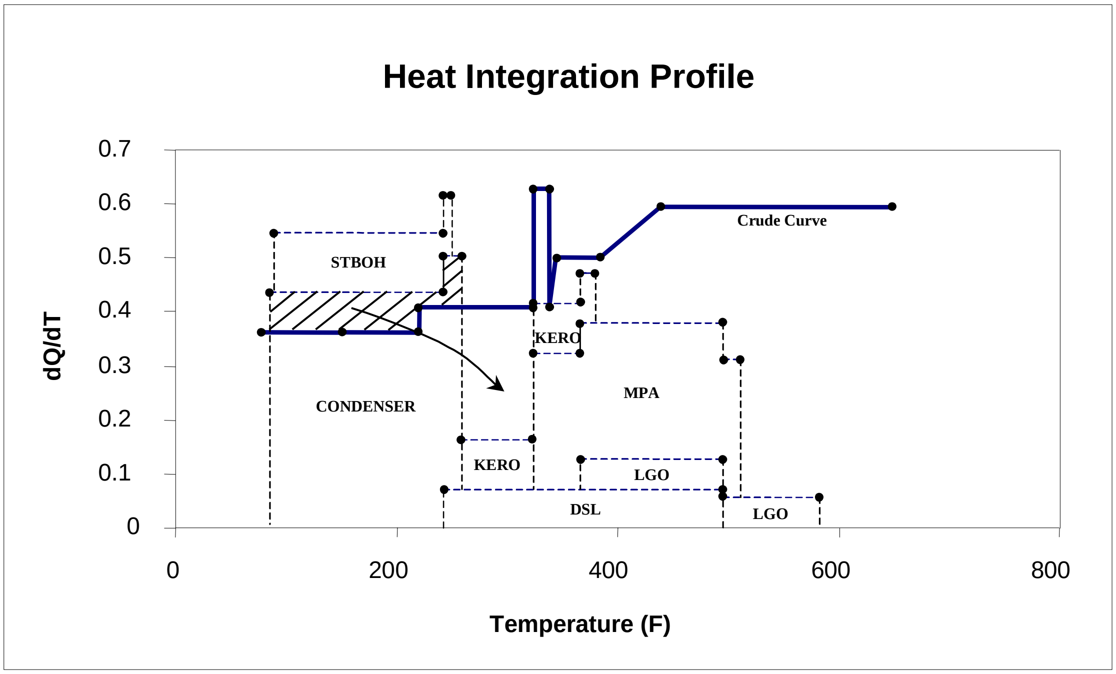

Figure 5

However, the existing equipment may not be able to deliver such variation in duty. Indeed, after performing the simulation varying the flowrate of the pumparound, only slightly decrease in the heating utility is observed. This is an indication that for the given temperatures the area installed is not enough for the task requested. Relocation of the return pipe is therefore proposed to increase the temperature of the pumparound. Important extra savings are obtained changing the return tray.

Table 3

	Retrofit Case	**Retrofit case with main column**
Capital Expenditure	$ 875,806	$ 925,806
Furnace load changes	31.5 MMBtu/hr	37.1 MMBtu/hr
Steam savings	3.1 MMBtu/hr	3.2 MMBtu/hr
Total Savings	34.6 MMBtu/hr	40.3 MMBtu/hr
Payout	1.2 years	1.1 years

CONCLUSIONS

A retrofit procedure was applied to a Crude Topping Unit. This procedure revealed great opportunities for obtaining energy savings. Implementation of part of these opportunities was proposed and the feasibility of the changes was evaluated. A retrofit design was presented and economical evaluation of its implementation was performed.