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OPTIMISING ENERGY CONSUMPTION OF DISTILLATION UNIT

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ABSTRACT

This work aims to develop and validate a methodology for the rationalization of energy consumption and improving energy efficiency (EE) of an oil refinery. The proposal includes an elaborate set of step i) identification of loss / energy deposits ii) the optimal design a network of heat exchangers by means of the thermal pinch iii) the implementation of heat pumps to reduce energy consumption in the reboiler.

Keywords: *energy efficiency; heat pumps; thermal pinch; network of heat exchangers.*

INTRODUCTION

Currently, it is important to mention that several factors affect the evolution of the petrochemical industry namely: radical increase in oil prices, environmental regulations and especially the energy consumption of the refining process is extremely high. The methods for saving energy in petrochemical processes are based on optimizing optimum process conditions for instructions, maintenance of heat exchangers networks (HEN) and thermal cracking furnaces, however, re-design of the HEN is considerably appropriate. The design of a HEN requires determining the lowest cost in the number of heat exchanger, their location and their exchange area, this combinatorial optimization problem will be addressed including thermodynamically using the thermal pinch method (TPM) [1,2]. The use of the TPM for energy integration was applied in a efficient manner on several industrial processes for producing ethylbenzene, [3] and ethanol distillation [4,5]. In the present work we combine the optimal design of HEN with a heat pump between the boiler and condenser. This combination minimizes the external demand for energy on the other hand the oven uses less energy and the boiler will pump energy usually lost during the condensation of the distillate.

Ultimately, the approach proposed a generic methodology that considers primarily the monitoring of consumption to identify losses and therefore the potential for energy savings; Secondly we focus on the rationalization of energy consumption through reducing waste and increasing energy efficiency of the equipment in use a methodology incorporating i) the optimal design of heat exchangers ii) setting instead of a device for the connection between the condenser and the reboiler. The case study considered for the development of the approach is an atmospheric distillation unit consisting of a heat exchanger train, a desalter, and an atmospheric oven.

RATIONALIZATION OF ENERGY CONSUMPTION

The diagnosis and identification of heat losses in the atmospheric distillation process is a crucial step in understanding the principle of the optimization of the energy consumption of the unit. In the present work, we considered all the equipment used in the generation, transfer and transport of energy namely: ovens, the column, the desalter, the process of heat exchange, condenser (eg air coolers) reboiler and pipes of the unit under study.

Primarily the furnace allows a thermal cracking of the oil molecules, and increasing the temperature of the hydrocarbon mixture at a temperature of about 370 ° C favoring the distillation process. From an energy standpoint, the amount of waste heat in the furnace is the difference between the total energy input and useful energy, it includes losses fumes away by the hot gases coming out of the chimney (the energy lost by the flue gases can be exploited through an exchanger and whereas the corrosive effect of the gas [6]) and by the heat exchange by radiation and convection between the air and the hot walls of the furnace. These losses walls are of the order of 3% of PCI [7] if the walls are refractory surface otherwise the losses are given by the first part of the expression below. The non-refractory surface is determined by an infrared thermography is generally in the range [18% - 22%] to the vertical furnaces typically used in refineries. Finally, smoked losses are calculated through the equation (1), those walls are calculated by equation (2) and Table 1 summarizes typical thermal losses with the corresponding standards.

$$Q_F^P = d_F . C_{PF} . (T_F - T_A) \tag{1}$$

$$Q_P^P = k_e S(T_i - T_e) + 3\% . \frac{PCI_{FuelGaz} + PCI_{FuelOil}}{100} \tag{2}$$

Table 1 : Summary of heat loss in the furnace vs standards.

	Q_F^P (KW)	Q_P^P (KW)
Standards	5-20%	2%
Furnace	38,2	669
Total	85,8	1396,5

Generally, all heat exchangers used for preheating the crude types are tubular-type shell and tube operating in against the tide. In principle the heat exchanger network (HEN) consists of 22 devices connected in series which 6 are located before the desalter (cold process HENC) and 16 post (hot process HENH). Losses of the process of exchange is calculated based on equation (3) representing the difference in observed temperature (real) and the design (in the best operating conditions of the heat exchangers), Table 2 illustrates the all thermal losses of both hot and cold trains.

$$Q_{ec}^P = \dot{m} . C_P . \left(T^{ref} - T^{reel}\right) \tag{3}$$

Table 2 : Thermal losses in HEN .

	T^{ref} (°C)	T^{reel} (°C)	Q^{P}_{ec} (KW)
Cold	129	109	1615
Hot	267	252	3642
Total	267	252	5257

The cooling towers allow condensation and cooling of the head product of the distillation column to achieve optimal storage conditions. The losses in these devices are mainly due to fouling and plugging of the tubes. Products that have not reached their storage temperatures and pressure are supplied to the torch, the corresponding flow rate is of the order of 1 t / h (1.2% of fuel oil equivalent) accordingly the losses at the condenser is of order of 3200KW.

Finally, loss of energy dissipation at the piping and insulation are considered. To calculate these losses it is important to identify the insulation used (conductivity coefficients) and its thickness. These losses of 2511 kW with 89.6% loss of the non-insulated pipe.

The analysis of four components designed for the identification of losses clearly shows that the HEN represents approximately 50% of total energy losses followed by aero-refrigerate and piping.

DESIGN OF AN OPTIMAL HEAT EXCHANGER NETWORK (HEN)

To design the optimal HEN is intended energy savings for integrating sensitive heats of 7 extractions side of the column for preheating the crude. This design will minimize external demand for heat and cold while specifying the number of heat exchangers to deploy, their locations and their exchange surface. The methodology adopted to solve this combinatorial optimization problem is the use of the thermal pinch method (TMP) and its implementation with the calculation tool "Heat Integration" [8]

The composite curves (CC) to determine the actual demand for heating and cooling and therefore to identify the overall potential of energy integration. For the development of CC it was based on the assumption that both hot and cold trains are considered a single train. Flows to integrate with their inlet temperatures, output, and enthalpy are shown in Table 3.

Table 3 : Data for the development of composite curves

Stream	Description	Type	Temprature (K) Input	Temprature Output (K)	H(Kw)	mcp (Kw/K)
1	Brut	Cold	295	614	33782.1	105.9
2	R S	Hot	419	349	-6947.5	99.3
3	R K	Hot	471	399	-6345.2	88.1
4	FO	Hot	599	353	-16461	66.9
5	K	Hot	496	311	-2874.9	15.5
6	GO1	Hot	504	318	-7311.6	39.8
7	Reflux GO1	Hot	525	485	-5392	134.8
8	Reflux GO2	Hot	595	567	-466.9	16.6

The composite curves, corresponding to a ΔTmin, are shown in Figure 1. The value of the hot fluid side pinch temperature is 252 242 ° C and cold-side fluid [9]. Finally, we deduce from CC that there is a need to warm in 5065 KW, a cold in need of 17,083 KW and a quantity of heat built 28,716 kW; while the usual hot demand in such a situation is 44636 KW and cold demand is 20,594 KW.

Moreover, each change of slope in the hot composite curve (upper curve in Figure 1) is a heat exchanger to put up with in particular the cross-flow, the temperature input / output, and the amount of heat exchanged in each exchanger (heating surfaces). Table 4 summarizes the optimum REC data.

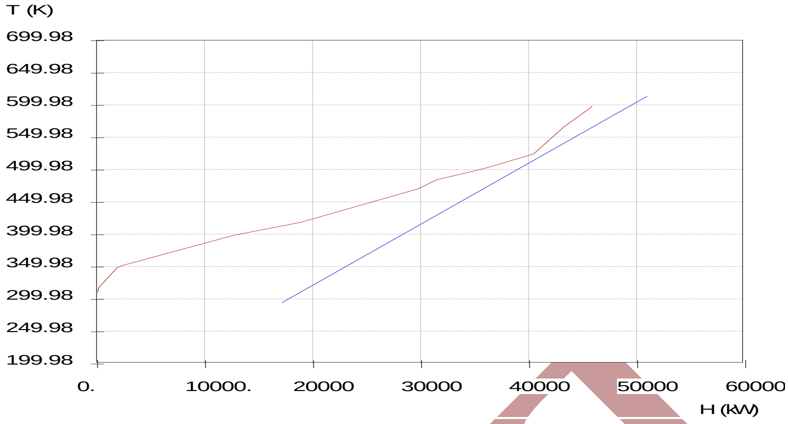

Figure 1: hot and cold composite curves

Compared with the existing REC and the proposed hot demand fell by 77%, and cold demand increased by 65%. Note that for the same amount of heat, cooling the cost is less than 66% of heating cost.

Table 4 : Characteristics of the proposed HEN

.	Heat Flux (kW)	Hot Flux	T1 (K)	T2 (K)	Cold Flux	T1 (K)	T2 (K)	Surface (m2)
1	4951,7	FO	599	525	brut	515	561	239,03
2	5392,0	reflux GO1	525	485	brut	464	515	364,58
3	466,9	reflux GO2	595	567	Brut	561	566	33,756
4	2874,9	K	496	311	Brut	295	322	43,458
5	6947,5	R S	419	349	Brut	322	387	239,64
6	8083,6	FO	525	404	Brut	387	464	238,08

ENERGY INTEGRATION : HEAT PUMP (HP)

Heat losses in the cooling tower is placed in second position losses / energy deposits with approximately 30% of the losses of the unit. Of these 30.6%, a 51% is occupied by a flying condenser overhead vapors from the distillation column. The losses accompanying the need for an external heat input at the reboiler of the column attributed to the decrease in energy efficiency. To an atmospheric distillation column consumes a power of 2601 KW in the reboiler. The power available in the overheads (condenser) of the distillation column is in the order of 22,289 KW. The amounts of energy required for the distillation process can be thus reduced through the use of heat pumps to recover heat from the condenser and provide the reboiler. Hence the importance of energy integration between the condenser and the boiler of the column. The alternative applied in this work is a heat pump (HP) allowing vapor to be condensed head by an external heat transfer fluid that will serve as a source of energy in the boiler [10].

On the other alternatives can be used including vapor compression or flash reboiler (see Figure 2), however, both alternative uses the steam as clean coolant which can cause complications

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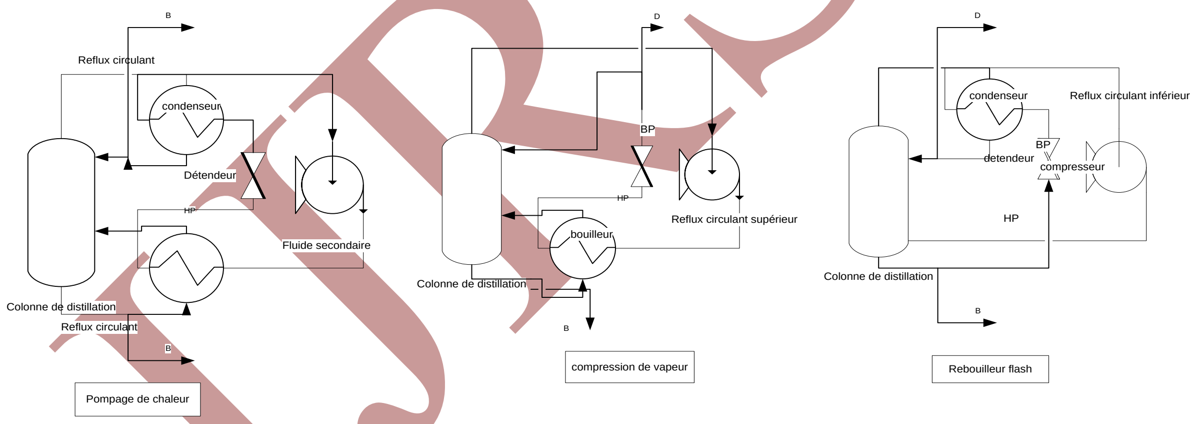

Figure 2: Integration diagram of a distillation column

The choice of coolant is strictly conditioned by the operating parameters of the distillation column. To promote heat transfer from the heat transfer fluid to the reboiler, the fluid temperature should be higher than the steam temperature. Note that it reaches 345 ° C. From these constraints, the dry, filtered air is the most suitable fluid for such application: It can reach very high temperature without its composition or its physical properties vary;
The calculation of parameters is based on relations of the polytropic transformations at the compressor and the turbine. The cycle parameters are shown in Figure 3.

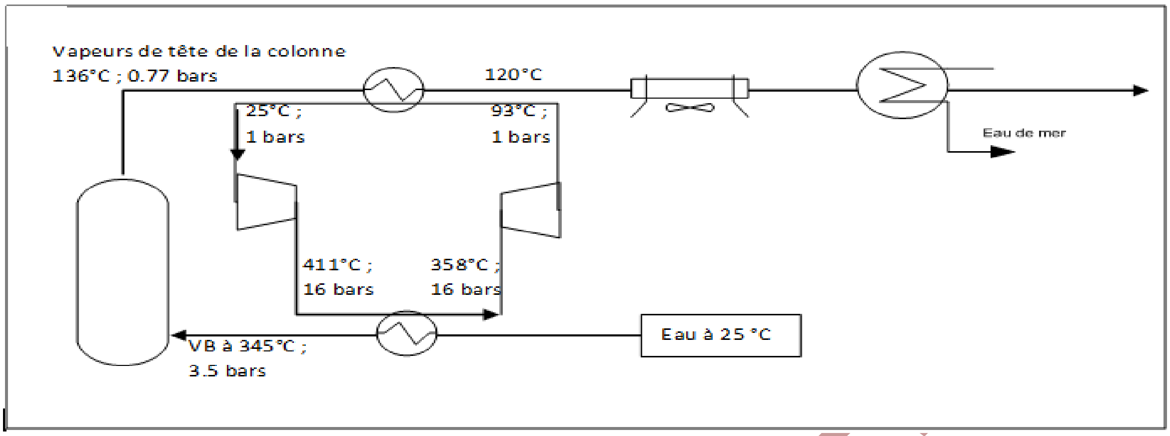

Figure 3 *: Location and heat pump operating parameters*

Centrifugal compressors can be adapted to high compression ratio (equation 5) and the corresponding driving power is given by equation (4).

$$W_{comp} = \varepsilon\left(\frac{n}{n-1}\right)T_{SF}\, r' \, \left(\left(\frac{HP}{BP}\right)^{\frac{n-1}{n}}\right. \quad (4)$$

$$\tau = \frac{HP}{BP} \quad (5)$$

Expander is a member for expanding the heat transfer fluid to the passing of a pressure and high temperature at considerably lower pressures and temperatures.

It is very important to mention that the energy consumption at the compressor is relatively high (it is in the range of 11000 W) however in this work it is proposed to change the expansion valve in the cap by a turbine. Starting from a thermal energy, the turbine converts this energy into kinetic energy which is transmitted to a rotating shaft serving to drive the compressor which reduces the energy consumption of the HP.

The HP a coefficient of performance (COP) of 0.76 against 0.8 for an ideal cycle (real HP is close to the ideal COP. The regulator circuit being a turbine, power is calculated from equation (6):

$$W_{turb} = \left(\frac{n}{(n-1)*\varepsilon}\right)T_{SC}\, r' \, \left(\left(\frac{BP}{HP}\right)^{\frac{(n-1)}{n}} - 1\right) \quad (6)$$

Table 4

	Power en KW	Compression rate
Compressor	11 167	16
Valve	20.245	

At the level of the cold source (the air condenser) heat exchange takes place between the head of the column of vapor and air in a heat exchanger bundle-like grille, where the column head vapors circulating in inside the tubes. Furthermore, at the heat source (the reboiler), the heat exchange is also carried out in an exchanger-type calender beam between the steam reboiler of the column and air. Air flows inside the tubes, the specifications of the heat exchangers for the two sources are shown in Table 5.

Table 5 : Characteristics of the heat exchangers of the heat pump

	Cold source (Heat Exchanger)	Hot source (Heat Exchanger)
Surface (m²)	674,8	58
Power en KW	2 980,7	2 601,9
DTLM	62,52	153,19
Global exchange coefficient W/m² K	119,6	410,8
Number of tube	4520	4520

The installation of the heat pump will allow saving of 2 601KW at the reboiler of the column. The compressor power demand is 11 167KW, or the power supplied by the turbine 20 is 245KW. It thus will ensure all the required compressor power. In conclusion the savings will be 2 601KW.

CONCLUSION

The proposals developed in this work show the importance of the implementation of energy integration in industrial processes including petroleum refining. This integration allows effective rationalization of energy by the reduction to minimum level of external demand for heating and cooling. The study is based on the thermal pinch method and the energy recovery through integration of a heat pump.

The present work uses the thermal pinch method for the integration of the heat exchange process for designing an optimal network exchanger, reliable and less energy. In particular, the proposed network exchanger to a total exchange surface two times less than the surface of the existing exchanger network and that allows a heat recovery of 10.6% more, with a decrease of 22.7 % of the external supply of heating, which promotes a 23.7% saving in fuel prices.

The exploitation of the approach considered in this work helped to highlight optimization by juxtaposing the energy requirement in the reboiler of the distillation column and the heat given off by the overhead vapors of the same column. This approach is achieved by the introduction of a Heat Pump using as coolant dry air filtered fluid to not harm its equipment. The compression of the air requires external supply of energy, has arisen by the idea of driving the mechanical compressor by a shaft connected to a turbine that will play the role of regulator in the da CAP cycle and ensure the all of the power required by the compressor and energy costs were down 90%.

Finally, the study helped to minimize external energy inputs in an oil refining unit regardless of the complexity of the network involved. Integration has contributed to the decrease of 40.6% of the cost operating unit which mainly in energy cost.

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