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Minimization of the process loss in condensate fractionation plant

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Abstract

In this paper, the optimum design, operation and control philosophy were studied to minimize the process losses in a condensate fractionation plant. Pinch analysis was done for optimum energy usage in the plant. Energy losses once identified can be reduced with little investment. Remarkable savings can be obtained through an energy saving program. Important savings can also be made with operational improvements in the process and better maintenance of production equipment such as distillation column, heaters, heat exchangers etc. Saving energy and proper maintenance of equipments in the process will also reduce the amount of gas emissions and fuel gas consumption and increase plant's lifetime. Aspen- HYSYS and Aspen Energy Analyzer was used as a process simulator and energy analyzer accordingly. Study on energy savings, operating conditions and its environmental impact in a local fractionation plant is presented.

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Keywords: Process loss optimization; oil fractionation; simulation; HYSYS; Aspen energy analyzer.

1. Introduction

Chemical and petrochemical process industries are increasingly compelled to operate profitably in a very dynamic and global market. The increasing competition in the international arena and stringent product requirements mean decreasing profit margins unless plant operations are optimized dynamically to adapt to the changing market conditions and to reduce the operating cost [1]. For optimizing the crude oil operations, different solution approach was discussed in Ref. [2].

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Today in the industry, the design and optimization procedures have the trend to identify the configurations where the less energy consumption can be achieved. The energy savings results the environmental and economic saving for the various industrial applications can be diverse and very useful nowadays, when the search of new energy resources. Because the scarcity of traditional fuels and the instability in the global markets demand that the industry maximizes their efforts in the energy consumption optimization. The use of Pinch Technology allows finding the balance between energy and costs as well as the correct location of Utilities and Heat Exchangers [3]. Heat Exchangers Network shows the optimized path of hot & cold streams through the exchangers.

Pinch analysis is a methodology for minimising energy consumption of chemical processes by calculating thermodynamically feasible energy targets (minimum energy consumption) and achieving them by optimising the heat recovery systems, energy supply methods, and process operating conditions. This technology is useful when integrating HEN in chemical plants as it reduces capital costs and decreases specific energy demands [4].

Aspen HYSYS is one such software which is widely accepted and used for refinery simulation. Aspen HYSYS contains an oil manager which organizes the data for the pseudo-components separately. Simulation is a useful tool to study the output by a major change in the traditional design of a fractionation column [5]. AspenTech software is used because its strength in the simulation of hydrocarbon processes and the peculiarities makes it suitable for the Energy Integration Process. Aspen Energy Analyzer is well known software to analyze and optimize the energy required in a process plant.

Nomenclature

DT_{min}	Minimum Temperature Difference
E	Exchanger
HEN	Heat Exchanger Network

2. Simulation of condensate fractionation plant

The condensate fractionation unit is composed by the following equipment:

Three pre-heater (heat exchangers), one main distillation column and column reboiler, onekerosene stripper and kerosene reboiler, other exchangers, vessels, pumps and utilities. The objective of this simulation was to provide the required heat load data to Aspen energy analyzer for Heat Exchanger Networking (HEN), pinch analysis and economic summery.

The simulation was done in HYSYS to regenerate the data. The simulation model column can be seen in Fig. 1. Among the three products, MS (Motor Spirit) was the top product and it was the lightest of all. . Kerosene was the side draw from the column. It was composed of mostly medium heavy oil components. Diesel was the bottom product of the column and heaviest of all. The raw condensate fed to feed pre-heaters in fractionation area. At first feed pre-heater condensate pre-heated by kerosene products and then it goes to another feed-preheater E-101 and heated up by diesel products. Then finally the condensate pre-heated at heat exchanger E-102 by heat transfer oil (thermal oil) coming from thermal oil heater to enrich with sufficient temperature before fed into fractionation column.

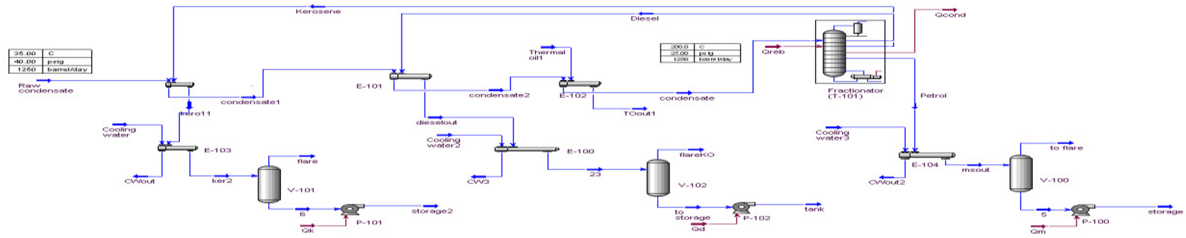

Fig. 1.Process simulation model for condensate fractionation plant.

3. Pinch analysis

Pinch analysis is a systematic technique for analyzing heat flow through an industrial process based on fundamental thermodynamics. The second law of thermodynamics requires the heat flow naturally from hot to cold objects. This key concept is embodied in the hot and cold composite curves (Fig. 3), which represent the overall heat release and heat demand of a process as a function of temperature [6].

Based on the above simulation model (Fig. 1) the hot streams and cold streams are listed below (Fig. 2) with their operating condition and different properties. This was accumulated by Aspen Energy Analyzer.

Name		Inlet T [C]	Outlet T [C]	MCp [kJ/C-h]	Enthalpy [kJ/h]	Segm.	HTC [kJ/h-m2-C]	Flowrate [kg/h]	Effective Cp [kJ/kg-C]	DT Cont. [C]
Kerosene_To_ker2		204.0	35.0	---	6.486e+005		---	1717	---	Global
Raw condensate_To_condensate		35.0	200.0	---	3.625e+006		---	6724	---	Global
Cooling water_To_CWout		30.0	35.0	6.494e+004	3.247e+005		14710.6	1.508e+00	4.307	Global
Cooling water2_To_CW3		30.0	35.0	1.990e+004	9.952e+004		14710.6	4621	4.307	Global
Cooling water3_To_CWout2		30.0	35.0	19.77	98.87		14710.6	4.591	4.307	Global
Petrol_To_msout		35.0	34.5	197.7	98.87		20616.3	3200	308.9	Global
Diesel_To_23		280.9	35.0	---	1.037e+006		---	1807	---	Global
Thermal oil1_To_TOout1		316.0	304.0	1.969e+005	2.363e+006		4250.8	8.928e+00	2.206	Global
To Condenser@COL1_TO_MS@COL1		123.2	35.0	---	4.949e+006		---	9601	---	Global
To Reboiler@COL1_TO_Boilup@COL1		272.4	280.9	---	2.604e+006		---	1.131e+00	---	Global
kerosene stripper_ToReb@COL1_TO_Kerosene@CO		198.5	204.0	6.889e+004	3.850e+005		7750.5	2937	23.45	Global

Fig. 2. Conditions & properties of hot streams and cold streams in the plant

3.1. Typical DT_{min} values for various types of processes

Table 1 shows typical DT_{min} values for several types of processes. These are values based on Linnhoff March's application experience [7].

It is important to note that although experience based DT_{min} values can provide practical targets for retrofit modifications, in certain situations it may result in non-optimal solutions and therefore loss of potential opportunities. It is therefore recommended that the use of experience based DT_{min} is treated with caution and that as much as possible the choice is backed up by quantitative information (such as DT_{min} versus energy plot etc.).

Table 1. Typical DT_{min} values

No	Industrial Sector	Experience DT_{min} Values	Comments
1	Oil Refining	20-40ºC	Relatively low heat transfer coefficients, parallel composite curves in many applications, fouling of heat exchangers
2	Petrochemical	10-20ºC	Reboiling and condensing duties provide better heat transfer coefficients, low fouling
3	Chemical	10-20ºC	As for Petrochemicals
4	Low Temperature Processes	3-5ºC	Power requirement for refrigeration system is very expensive. DTmin decreases with low refrigeration temperatures

3.2. Composite Curves

Composite Curves consist of temperature-enthalpy (T-H) profiles of heat availability in the process (the "hot composite curve") and heat demands in the process (the "cold composite curve") together in a graphical representation [6]. Fig. 3 illustrates the construction of the "hot composite curve" for the fractionation process, which has five hot streams (stream number 1,6,7,8 and 9, see Fig. 2). Their T-H representation and composite representation is shown in Fig. 3. In PinchExpress, an option for automatically calculating a suitable DT_{min} for a process is available. This calculation is done by considering an area-energy trade-off based on one of two benchmark processes built in to PinchExpress. These processes are used as they represent two extremes of plant economics. The DT_{min} for pinch point was found for this process is 10.5°C, where for hot stream 123.2 °C and for cold stream 112.7 °C (Fig. 3).

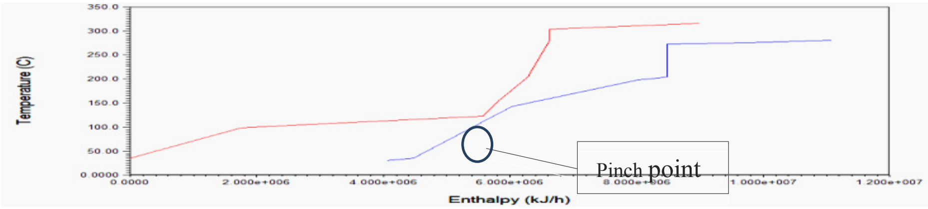

Fig. 3. Pinch point for hot and cold streams represented by composite curves.

3.3. Heat Exchangers Networks (HEN)

The optimal Heat Exchanger Networks (HEN's) were obtained according the above pinch, comparing on different ΔTmin values. With the use of the Aspen Energy Analyzer software, the optimal designs are obtained, where a reduction in the utilities consumption is achieved, saving operating costs, getting a balance between operative and capital costs with economical KPI's (Key Performance Indicators) as return over investments (ROI) and Equipment Index Costs, etc.

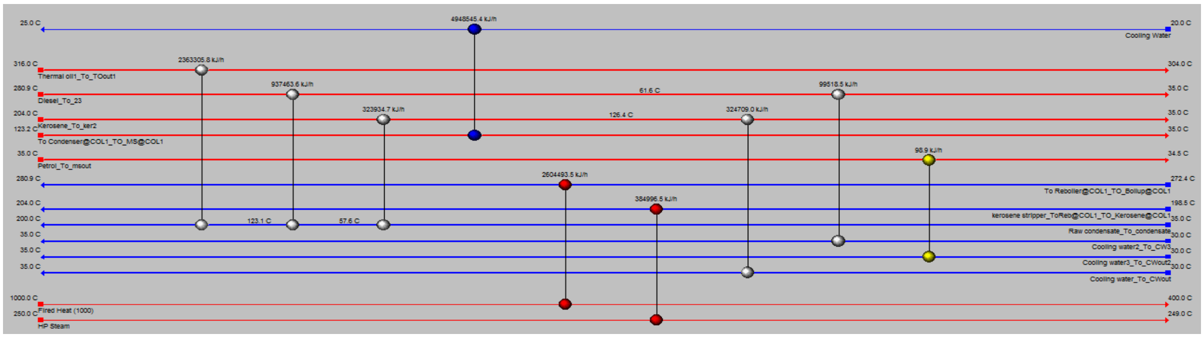

Fig. 4. Network design for the current configuration of the fractionation Plant with DT = 10.5 °C.

The Fig. 5below showing the effect of DT_{min} on heat exchangers area and total cost index. Though here a lower DTmin, the total cost index is lower but we got the DT_{min} 10.5°C and the perspective costing and sizing will be based on the 10.5 °C. In the "Range Targets" chart we can easily evaluate the cost index by graphical representation.

a

DTmin [C]	Heating [kJ/h]	Cooling [kJ/h]	Area 1 - 1 [m2]	Area 1 - 2 [m2]	Units	Shells	Cap. Cost Index [Cost]	Op. Cost Index [Cost/s]	Total Cost Index [Cost/s]
2.0	1.971e+006	3.931e+006	127.1	134.6	15	47	2.897e+005	1.704e-003	4.662e-003
3.0	1.986e+006	3.945e+006	119.4	125.8	15	45	2.847e+005	1.717e-003	4.624e-003
4.0	2.000e+006	3.959e+006	114.0	119.7	15	45	2.818e+005	1.730e-003	4.608e-003
5.0	2.014e+006	3.973e+006	109.9	115.1	15	39	2.776e+005	1.743e-003	4.578e-003
6.0	2.028e+006	3.987e+006	106.8	111.5	15	43	2.775e+005	1.755e-003	4.590e-003
6.0	2.029e+006	3.988e+006	106.7	111.4	15	43	2.774e+005	1.756e-003	4.590e-003
7.0	2.043e+006	4.002e+006	104.0	108.4	15	42	2.758e+005	1.769e-003	4.586e-003
8.0	2.057e+006	4.016e+006	101.7	105.8	15	42	2.748e+005	1.782e-003	4.589e-003
8.3	2.062e+006	4.021e+006	101.0	105.0	15	42	2.745e+005	1.786e-003	4.590e-003
9.0	2.072e+006	4.031e+006	99.8	103.7	14	41	2.619e+005	1.794e-003	4.469e-003
9.9	2.085e+006	4.044e+006	98.3	102.0	14	39	2.603e+005	1.804e-003	4.463e-003
10.0	2.086e+006	4.045e+006	98.2	101.9	14	39	2.602e+005	1.805e-003	4.463e-003
11.0	2.100e+006	4.059e+006	96.8	100.2	14	39	2.594e+005	1.815e-003	4.464e-003
11.5	2.107e+006	4.067e+006	96.1	99.4	14	39	2.590e+005	1.821e-003	4.466e-003
12.0	2.115e+006	4.074e+006	95.5	98.7	14	39	2.586e+005	1.826e-003	4.467e-003
13.0	2.129e+006	4.088e+006	94.3	97.4	14	39	2.579e+005	1.837e-003	4.471e-003
13.9	2.141e+006	4.101e+006	93.4	96.4	14	39	2.573e+005	1.846e-003	4.475e-003
14.0	2.143e+006	4.102e+006	93.3	96.2	14	39	2.572e+005	1.848e-003	4.475e-003
15.0	2.158e+006	4.117e+006	---	---	---	---	---	---	---
16.0	2.172e+006	4.131e+006	---	---	---	---	---	---	---
17.0	2.186e+006	4.145e+006	---	---	---	---	---	---	---
17.0	2.187e+006	4.146e+006	---	---	---	---	---	---	---
18.0	2.201e+006	4.160e+006	---	---	---	---	---	---	---
28.0	2.344e+006	4.303e+006	---	---	---	---	---	---	---
44.0	2.604e+006	4.564e+006	---	---	---	---	---	---	---

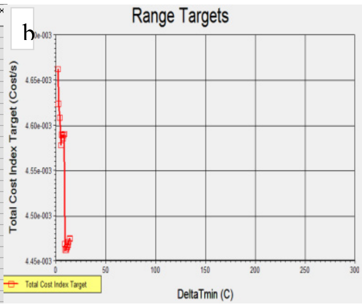

Fig. 5. (a) Effect of DT_{min} on heat exchangers area and total cost index; (b) Graphical representation of Fig. 5. (a)

4. Ways allowing to carry out energy savings

There are several ways to carry out energy savings in the fractionation plant. The optimization of the operation of the refining units by a good adjustment of the operational parameters is an important action in the programmes of energy saving. Certain energy saving can be carried out without investments.

4.1. Control philosophy changes:

The improved pressure and temperature control philosophy as well as the changes to the trip settings improved the operational flexibility. This allowed for the light cut column to be controlled at its design operating pressure. The heavy cut column was however still operating at a deeper vacuum than intended.

4.2. Combustion control:

The combustion control system regulates the fuel air mixture to achieve efficient combustion.Using high excess air will lower the flame temperature by diluting the combustions gases and will increase volume of gases that exhausted from the process. Using low excess air will result in unburned fuel gas.The correct amount of excess air is determined from the analyses of flue gas oxygen or carbon dioxide concentrations using a flue gas analyser. The use of an on-line analyzer allows an effective follow-up of thefurnace operation [8].To guarantee correct operations, burners must be cleaned periodically and maintained regularly to ensure a good atomisation of fuel. The economic incentive to tune fired heaters generally follow the “80/20 Rule”, i.e., 80% of the savings can be achieved by focusing on 20% of the heaters. Large heaters with high stack temperatures generally provide the best opportunity for improvement [9].

4.3. Produce On-Spec Products

Two easy ways to waste energy in a process facility are to produce off-spec product and product at a better quality than necessary. Both need to be eliminated.Off-spec product is often recycled through the facility, consuming as much energy as it did the first time through and consuming valuable plant capacity. A careful review of the yield statement and the operator log will help pin-point the largest opportunities.

4.4. Optimize Feed Preheat Trains

This requires integrating heat sources to heat sinks in separate process units. Good engineering design practice balances the cost of incremental exchanger area against the energy savings.Exchanger fouling is also an area that is receiving considerably more attention.

4.5. Thermal losses reduction

The maintenance should be in good condition of the optimumheat insulation of pipes and tanks. This reduce the of heat losses from tanks as well as heat transfer equipment and piping consists in minimizing losses using an economic thickness and periodic repairs of damagedinsulation.

4.6. Reduce Pressure Drop Across Control Valves

Ideally, the centrifugal driver is sized to provide a reasonable pressure drop across the control valve, typically 10-15% of the total hydraulic losses or 10 psi, whichever is greater. If the driver is mis-matched with the hydraulic requirements, the system will balance itself by taking additional pressure drop across the control valve, consuming more horsepower than required for process control.

4.7. Design for Energy Efficiency the First Time

It is always easier to justify energy efficient technologies in the original design versus after the process equipment is engineered and constructed. For example, a good process engineer will balance the capital cost of additional distillation trays against the heat input requirements to affect a given separation [9].

4.8. Recovery of gases to the flare and reflux control

The recovery of gases sent to the flare by compression and their use as fuel gas in the network is a significant operation in the energy saving programs. The adjustment of the reflux for the operation of the fractionating column is important. It must be maintained at an optimal value in order to minimize the discharges of gases to the flare.

4.9. Use of new technologies

Pinch method, techniques of process simulation can be used to improve the power consumption of the industrial processes by optimizing the operating conditions using simulation softwares such as HYSYS, Energy Analyzer etc.

4.10. Energy Assessment Case Study

An energy pre audit was realized at a local refinery in order to improve the efficiency ofenergy usage as:

- Analyze the energy situation in the fractionation plant
- Measure and evaluate the performance of the energy consuming equipment
- Identify operational savings and recommend solutions with potential annual savings.

5. Conclusion

Different types of process loss in the condensate fractionation plant can be minimized with proper energy analysis initially in time of process design phase which makes important savings. The materials & heat loss in the running processes can also be optimized changing few process parameters like temperature, pressure and flowrate of products based on present conditions. Periodic maintenance plays an important role to achieve lower consumption of fuel, safe and healthy environment, increase the life-time of equipments and instruments, as well as whole refinery system.Pinch analysis is a very powerful technique for identifying minimum energy consumptions targets for heating and cooling and identifying projects to achieve significant energy savings. HEN shows the optimum paths of all process streams. The ways allowing tocarry out energy savings described above were effective. Best of all, many opportunities can be implemented with little or no capital.

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