Optimal pre-flash drum pressure and optimal inlet tray for pre-flashing vapor in a crude distillation unit

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Abstract

The Crude Oil Distillation Unit (CDU) plays a central role in petroleum refining. Building a new CDU is very expensive, so several retrofit projects must be considered on existing CDU facilities to increase production capacity and reduce energy consumption. The application of a pre-flash drum system to CDU in recent years has had a good effect on raising the performance of CDU, especially when dealing with light crude oil. In this paper, the existing CDU has been retrofitted to raise the performance of the unit, especially when dealing with light crude oil. The retrofit is based on the implementation of a pre-flash drum and pump after the crude oil heat exchanger network and just before the furnace. In addition, the present work determines the optimal pressure of the pre-flash drum and the optimal input tray of pre-flash vapors into the CDU. The choice of optimal values depends on the minimum power consumption of the CDU and the maximum obtained products. HYSYS simulation software version 11 was used. The results showed a reduction in CDU operating cost of 7.49% at the optimal pre-flash pressure and optimal input tray for pre-flashed vapors. The presented study can be used as a guide in retrofitting existing heavy crude oil units and units under design.

Keywords: Atmospheric Distillation, pre-flash drum, HYSYS simulation, light crude oil

1. Introduction

The Crude oil distillation unit is considered the backbone of any refinery process. It is regarded as a highly energy-intensive process [1].The existing CDUs consist of a heat exchanger network (HEN), furnace, and atmospheric distillation column with two pumps around and three side product strippers. Off gases and light naphtha are the overhead products. Heavy naphtha, kerosene, and atmospheric gas oil are side products while fuel oil is the bottom product. The design of existing

CDU in the petroleum industry is based on a distillation of heavy crude oils. In the case of light crude oil production from crude oil wells, bottleneck problems appear such as high vapor pressure of the liquid entering the furnace. Thus, it reduces the capacity of the heater coil and increases the energy wasted in the heater. A common and suggested modification that can be added to existing CDUs to improve their performance is pre-flash column or pre-flash drum. The Pre-flash column contains overhead system such as water condensers, drum, and overhead pumps. And the column trays increase the capital cost of the modifications compared to the pre-flash drum which does not have a top system and column trays [2, 3].

A pre-flash device is also added to separate the light vapors from the crude oil preheated in the HEN thus reducing the capacity of the liquid entering the furnace. The vapor stream obtained from the pre-flash device can then be introduced at the outlet of the furnace or at the appropriate location of the main crude distillation column. In this case, it is possible to reduce the furnace duty of the distillation unit. The optimal option is to insert the vapor product of the pre-flash drum into the upper trays of the distillation column to decrease the contact between the incoming vapor and the liquid falling from the upper trays in the crude distillation column; this will reduce the duty of the condenser [4].

The choice between the pre-flash drum and pre-flash column depends on the scope of the revamping work and the space constrictions of the plant [5,6].Pre-flash drums are preferred when it is necessary to increase the capacity of the plant. And it may be the best solution to reach considerable savings in the energy demands. It is the best option used in revamping projects to save energy and decrease CO_2 emissions [7,8].Adding a pre-flash drum to CDUs for improving performance is presented by many researchers [3-14].

In this paper, an existing operating CDU used for refining heavy crude oil was used. In some cases, the crude oil feed changes from heavy phase to light phase, so the vapor load generated by CDU becomes high and may lead to overlap. This problem was solved by reducing the capacity of the crude oil feed entering the CDU, but this led to a decrease in the amount of finished products. In this work, this existing CDU was modified by adding a pre-flash drum and pump to allow the existing CDU to process light and heavy crude oil.

In previous work in the literature, the pre-flash drum was placed between the heat exchanger network and the desalting unit. In this work, the position of the pre-flash drum in the CDU was proposed to be after the end of the heat exchanger network (HEN) and just before the furnace. Light vapors are separated from the crude oil in the pre-flash drum before entering the furnace and sent directly to the top tray in the Atmospheric Distillation Column (ADC). Accordingly, the required furnace and condenser duty will be reduced. The pre-flash drum is placed after all heat exchanger networks as it is used in both heavy and light crude oil feeding cases. If it is placed between the heat exchanger networks in the case of heavy crude oil operation, the oil will not receive the required flash temperature in the pre-flash drum.

The pre-flash drum is operated at low pressure and the furnace placed before ADC is operated at high pressure, so a pump is required to increase the pressure of the bottom product of the pre-flash drum entering the furnace. In this work, a pump is added at the bottom product of the pre-flash drum to increase the bottom product pressure from 1.5 g/cm^3 to the furnace pressure of 11 g/cm^3.

In this work, the effect of adding a pre-flash drum and pump on the performance of the atmospheric distillation column and the energy consumption of the CDU were studied.

In addition to the above, the optimum pre-flash drum pressure and the optimum feed tray of the pre-flash vapor entering the ADC are determined in this work. The optimum pre-flash drum pressure is determined based on the minimum energy consumption of the furnace and the pump while the best entering tray of pre-flash vapor is determined based on the maximum profit of the ADU.

2. Retrofit Design Methodology

A general methodology for comparative analyzes and retrofit design evaluations are presented in this section. This methodology mainly contains three stages of work. First, the existing CDU was simulated via Aspen HYSYS steady state with no new equipment added (main case study). Second, the existing CDU was simulated with the addition of a pre-flash drum plus pump using optimal operating conditions. Finally, the economic analyzer in HYSYS software was used to estimate the capital cost of the added pre-flash drum and the new pump and also the payback period. The simulation provides complete process information, such as stream temperature, pressure, and flow rate, which is essential for evaluating the total cost.

3. Process description:

The real existing crude oil distillation unit without a pre-flash drum is used as the main case study.

Light crude oil feed is transferred by a feed pump and is preheated in the first preheat train of HEN from 25 ^oC to 130 ^oC, then it passes through desalter to remove inorganic salts, impurities and, soluble metals, then it is preheated in the second train from 130 ^oC to 155 ^oC. Through the HEN, the light components of the feed stream get partial vaporization and then get vaporization for about 3 vol. % over flash in the furnace. In this case, energy is lost to heat the light vapors again inside the furnace coils and these vapors reduce the capacity of the furnace coils. Thus, it is going to raise the temperature inside the furnace from 155 ^oC to 277 ^oC. The outlet from the furnace is going to ADC.

The most important factors in the success of any model of crude columns are an accurate representation of the crude feed. Collecting the maximal possible process information is the best way to ensure that a model is valid for a variety of operating scenarios so these steps were followed. Data from the industrial existing CDU were collected and organized into data sets. Each data set represents an operating day of the unit. Each data set includes an analysis of all input and output streams like a new crude oil feed assay and products' properties such as weight percentage, specific gravity, ASTM distillation, …, etc.).In addition, each data set includes the operating conditions of basic requirements for initial column model. Typically, industrial data gathered and arranged into data sets were taken during a steady-state operation period to avoid incorrect results for the model.

3.1. Real plant data

The light crude oil Assay (API 33.6) is chosen from the HYSYS program and used as a feed to the existing ADC handling heavy crude oil. This light crude oil is operated in the existing ADC using a pre-flash drum and pump. The Real industry feed conditions and composition is illustrated in Table 1. Table 2 presents the product distribution and quality. The true boiling point (TBP) curve of this light crude oil Assay was determined by HYSYS and presented in Figure 1.

Table 1: Crude oil feed conditions and composition for light crude oil Assay

Light crude oil feed					
Temperature (°C)	155.0				
Pressure (kg/cm^2)	11.50				
Mass Flow (ton/h)	98.00				
Composition					
Component	mole fraction	Component	mole fraction	Component	mole fraction
Ethane	0.0007	170-180 °C	0.0189	390-400 °C	0.0008
Propane	0.0045	180-190 °C	0.0213	400-410 °C	0.0046
i-Butane	0.0048	190-200 °C	0.0148	410-420 °C	0.0066
n-Butane	0.0195	200-210 °C	0.0132	420-430 °C	0.0092
i-Pentane	0.0290	210-220 °C	0.0151	430-440 °C	0.0100
2M-1-butene	0.0000	220-230 °C	0.0153	440-450 °C	0.0099
n-Pentane	0.0523	230-240 °C	0.0232	450-460 °C	0.0077
2M-2-butene	0.0017	240-250 °C	0.0132	460-480 °C	0.0131
Cyclopentane	0.0042	250-260 °C	0.0146	480-500 °C	0.0105
40-50 °C	0.0287	260-270 °C	0.0132	500-520 °C	0.0095
50-60 °C	0.0360	270-280 °C	0.0138	520-540 °C	0.0187
60-70 °C	0.0425	280-290 °C	0.0107	540-560 °C	0.0148
70-80 °C	0.0442	290-300 °C	0.0099	560-580 °C	0.0125
80-90 °C	0.0144	300-310 °C	0.0099	580-600 °C	0.0104
90-100 °C	0.0735	310-320 °C	0.0098	600-625 °C	0.0112
100-110 °C	0.0271	320-330 °C	0.0123	625-650 °C	0.0088
110-120 °C	0.0322	330-340 °C	0.0066	650-675 °C	0.0064
120-130 °C	0.0318	340-350 °C	0.0084	675-700 °C	0.0046
130-140 °C	0.0303	350-360 °C	0.0089	700-725 °C	0.0031
140-150 °C	0.0257	360-370 °C	0.0160	725-750 °C	0.0017
150-160 °C	0.0216	370-380 °C	0.0049	750-775 °C	0.0029
160-170 °C	0.0230	380-390 °C	0.0013		

Table 2: Real industry products distribution and quality for light crude oil Assay

ASTM D86 Vol%	LN (Ton/hr.)	Kerosene (Ton/hr.)	Gas oil (Ton/hr.)	Fuel oil (Ton/hr.)
10	56	168	234	-
20	68	171	-	-
30	78	174	-	-
40	-	-	-	-
50	96	180	250	-
60	104	182	-	-
70	113	185	-	-
80	-	-	300	-
90	-	196	335	-
FBP	160	215	370	-
SG 60/60	0.7106	0.7911	0.8432	0.9497

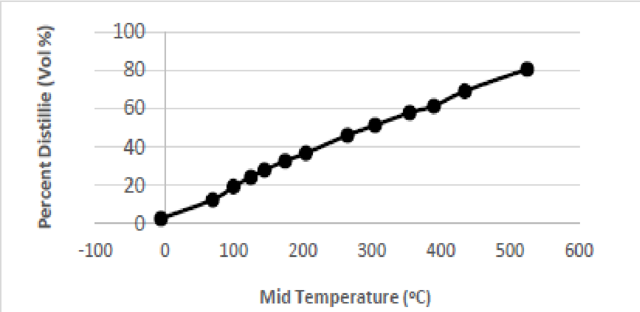

Figure 1: TBP curve from real industry assay data of light crude oil Assay (33.6 API)

4. Results and discussion

4.1. Simulation of the main case

Aspen HYSYS version 11 is used to simulate steady-state real existing atmospheric distillation unit using the light crude oil assay (33.6 API). The existing ADU is simulated in two cases, with and without using a pre-flash drum for processing the light crude oil. Figures 2 and 3 show the simulation of the existing ADU handling light crude oil in the base case without adding any new devices. Figure 3 shows the column environment. The simulation results of the ADU are presented in Table 3.

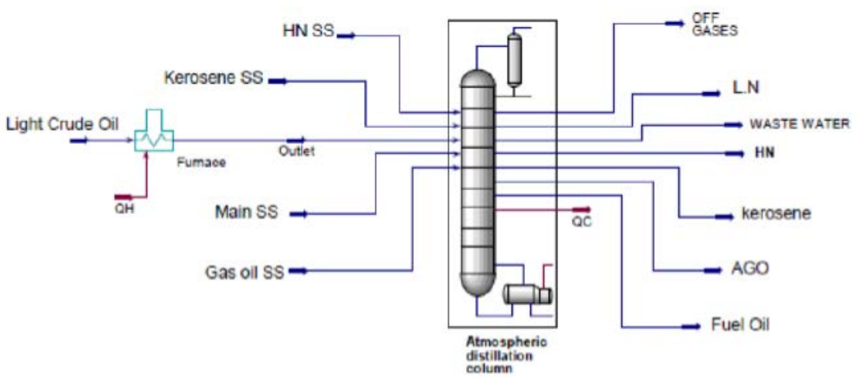

Figure 2: Flow sheet of Existing Atmospheric distillation unit (ADU)

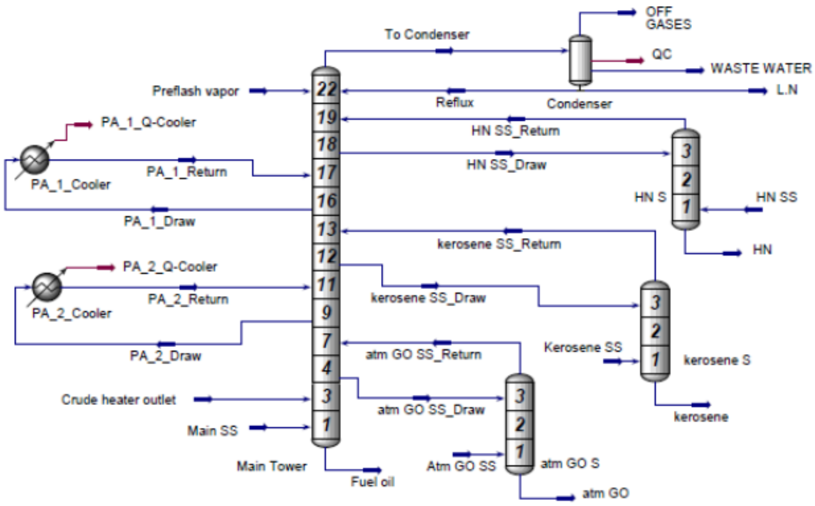

Figure 3: Atmospheric distillation column environment

Table 3: The simulation results of the base case (Figure 2) using light crude oil Assay (33.6 API)

Stream	Light Crude Oil	Outlet (Crude heater outlet)	OFF GASES	L.N	Main SS (steam)
Temperature (°C)	155.0	277.0	62.00	61.99	250.0
Pressure (kg/cm^2)	11.50	1.320	0.3200	0.3200	10.00
Mass Flow (ton/h)	98.00	98.00	1.053	24.10	1.260
Stream	Fuel Oil	WASTEWATER	HN SS	HN	Kerosene SS
Temperature (°C)	266.3	61.99	250.0	153.2	250.0
Pressure (kg/cm^2)	1.340	0.3200	10.00	0.9838	10.00
Mass Flow (ton/h)	56.85	3.163	0.0000	6.750e-009	1.000
Stream	kerosene	Gas oil SS	atm GO (AGO)	Reflux	To Condenser
Temperature (°C)	134.2	250.0	195.0	61.99	120.9
Pressure (kg/cm^2)	1.110	10.00	1.340	0.3200	0.9000
Mass Flow (ton/h)	5.273	1.000	10.82	22.52	50.84
Stream	HN SS_Draw	HN SS_Return	kerosene SS_Draw	kerosene SS_Return	PA_1_Draw (pump around 1)
Temperature (°C)	153.2	153.2	178.0	155.6	162.0
Pressure (kg/cm^2)	0.9838	0.9838	1.110	1.110	1.026
Mass Flow (ton/h)	6.750e-009	3.552e-016	8.672	4.399	30.00
Stream	PA_1_Return	PA_2_Draw (pump around 2)	PA_2_Return	atm GO SS_Draw	atm GO SS_Return
Temperature (°C)	102.0	195.9	95.85	228.6	214.8
Pressure (kg/cm^2)	1.026	1.172	1.172	1.277	1.277
Mass Flow (ton/h)	30.00	19.50	19.50	15.66	5.836
Stream	Atm GO SS	Pre-flash vapor			
Temperature (°C)	250.0	-			
Pressure (kg/cm^2)	10.00				
Mass Flow (ton/h)	1.000				

4.2. Model validation and testing

First, we must ensure that the main simulated model matches the industry baseline real column conditions and operating profiles. Kaes [15] has presented some guidelines to judge whether a model reflects the performance of a real column by using four checks. The top stage temperature and the bottom product temperature are checked by the column temperature profile shown in Figure 4. In the first check, the top stage temperature in the model column profile (121 ^{o}C) is higher than the top stage real column temperature (110^{o}C) by 11 ^{o}C within the range (7–15 °C). In the second check, the temperature of the bottom stream leaving the column model (266 °C) is lower than the feed temperature of the crude into the column model (272 °C) by 6 °C within the range (5–7 °C).

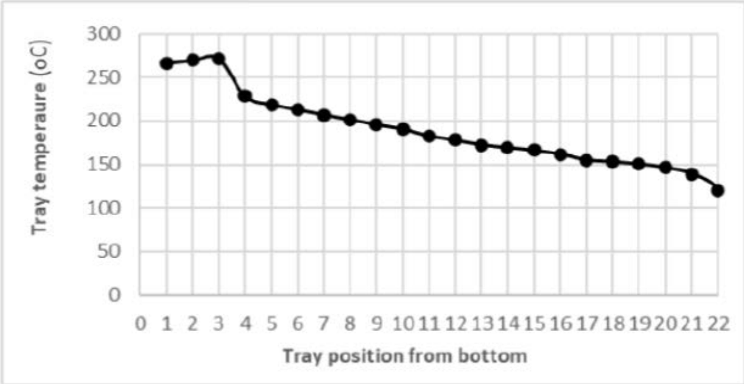

Figure 4: Column Temperature Profile

The third check, products flowrate from the model checked with the real industry products flowrate. Figure 5 shows the comparison between the results of the real industry case and the simulated case. It is noticed that the flowrate of off-gases, light naphtha (LN), kerosene, atmospheric gas oil (AGO) and, fuel oil of the real case and the simulated case are matched with each other.

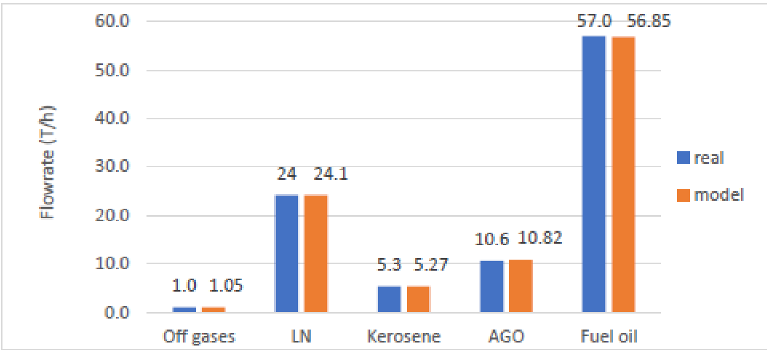

Figure 5: Products flowrate of the real and simulated model

The fourth check, the LN, Kerosene and, AGO quality from the simulated model are checked with ASTM D86 curve @ points 5% and 95% from real products laboratory analysis. By using light naphtha, kerosene and, atmospheric gas oil petroleum streams analysis and selecting boiling point curves (ASTM D86 curve) in the model and comparing with real value, the simulated model curve covers some points especially, @ points 5% and 95% as presented in Figures 6, 7 and 8 for the three products respectively.

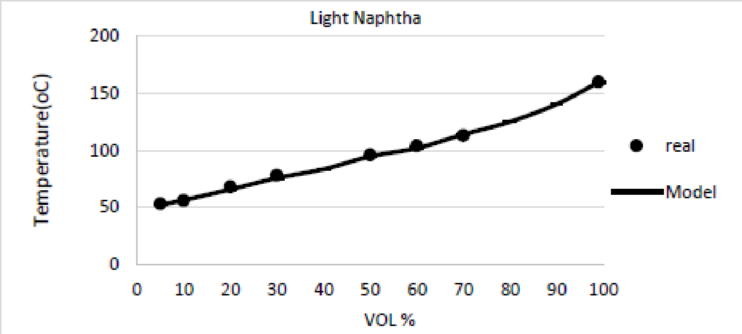

Figure 6: D-86 comparison curve for real and model (LN)

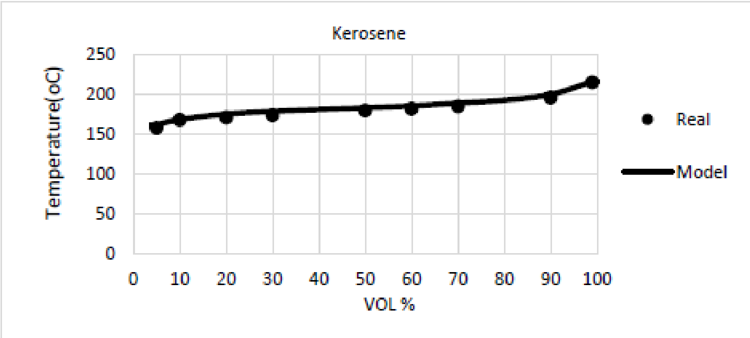

Figure 7: D-86 comparison curve for real and model (kerosene)

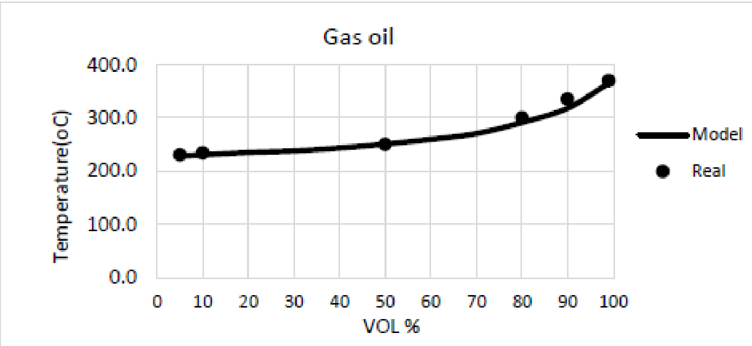

Figure 8: D-86 comparison curve for real and model (AGO)

In addition to the above, the specific gravity @60/60^{o}F of real products is checked with the specific gravity @60/60^{o}F of model products as shown in Figure 9.

All checks are in good agreement and we can use the model to study different operating scenarios and perform the retrofitted case.

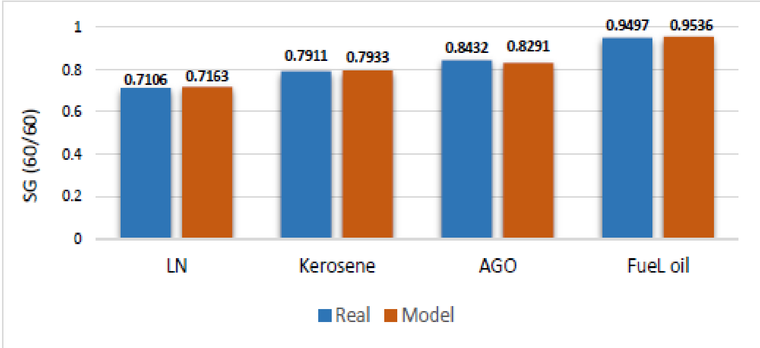

Figure 9: Comparison of real and simulated model product-specific gravities

4.2. Retrofitted Case

In this work, the existing CDU used for processing the heavy crude oil is retrofitted by implementing a pre-flash drum with optimum operating conditions and pump. The pre-flash drum was installed after the HEN and just before the furnace. The resulting vapors from the pre-flash drum are directly sent to the distillation column to the best tray that ensures minimum energy consumption as shown in Figure 10. The main function of the retrofit project in the existing unit is reducing its energy consumption. The side advantage of the retrofitted case is to ensure the design capacity of unit (125 Ton/hr.) without bottleneck in the furnace when handling light crude oil feed. The simulation results of the retrofitted case are illustrated in Table 4.

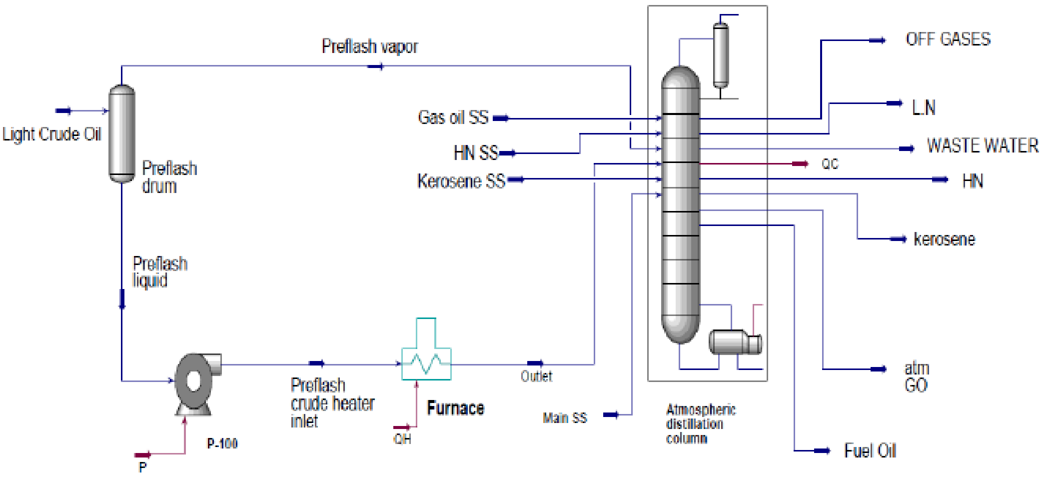

Figure 10: Flow sheet of the retrofitted case (Existing CDU with pre-flash drum)

Table 4: Simulation results of the retrofitted case

Stream	Light Crude Oil	Outlet (Crude heater outlet)	OFF GASES	L.N	Main SS (steam)
Temperature (ºC) Pressure (kg/cm^2) Mass Flow (ton/h)	155.0 11.50 98.00	277.0 1.320 89.62	62.03 0.3200 1.026	62.02 0.3200 24.30	250.0 10.00 1.260
Stream	Fuel Oil	WASTEWATER	HN SS	HN	Kerosene SS
Temperature (ºC) Pressure (kg/cm^2) Mass Flow (ton/h)	269.2 1.340 56.65	62.02 0.3200 3.163	250.0 10.00 0.0000	149.3 0.9838 6.750e-009	250.0 10.00 1.000
Stream	kerosene	Gas oil SS	atm GO	Reflux	To Condenser
Temperature (ºC) Pressure (kg/cm^2) Mass Flow (ton/h)	134.3 1.110 5.200	250.0 10.00 1.000	195.9 1.340 10.91	62.02 0.3200 14.29	120.1 0.9000 42.79
Stream	HN SS_Draw	HN SS_Return	kerosene SS_Draw	kerosene SS_Return	PA_1_Draw (pump around 1)
Temperature (ºC) Pressure (kg/cm^2) Mass Flow (ton/h)	149.3 0.9838 6.750e-009	1.0000 149.3 0.9838	177.8 1.110 8.523	155.6 1.110 4.323	159.5 1.026 30.00
Stream	PA_1_Return	PA_2_Draw (pump around 2)	PA_2_Return	atm GO SS_Draw	atm GO SS_Return
Temperature (ºC) Pressure (kg/cm^2) Mass Flow (ton/h)	99.54 1.026 30.00	197.6 1.172 19.50	97.58 1.172 19.50	230.9 1.277 16.03	216.3 1.277 6.119
Stream	Atm GO SS	Pre-flash vapor	Preflash liquid	Preflash crude heater	
Temperature (ºC) Pressure (kg/cm^2) Mass Flow (ton/h)	250.0 10.00 1.000	145.9 1.500 8.383	145.9 1.500 89.62	146.3 10.80 89.62	

4.4. Optimization of operating conditions of Pre-flash drum in the retrofitted case

It is found that the pre-flash drum pressure and feed tray of pre-flashed vapor in ADC are very effective parameters in the reduction of total operating cost for the retrofitted case. In the following section, the effects of these two parameters on energy consumption were studied.

4.4.1 Pre-flash drum pressure

The pre-flash drum pressure is a very important parameter to be considered for efficient energy management but it must be higher than the bottom operating pressure in ADC (1.35 kg/cm^2) with a suitable value to transfer the pre-flashed vapor to the best tray in ADC. According to the results obtained from the HYSYS program, the pre-flash drum pressure affects the flowrates of the separated pre-flash vapor and the pre-flash liquid, heating duty of the furnace and, pump power. The range of pre-flash drum pressure is taken as (1.4-8.0) kg/cm^2. It is found that increase in pressure above 4.5 kg/cm^2 results in no separation of light vapors. The optimum value of the pre-flash drum pressure is 1.5 kg/cm^2 as shown in Figure 11. At this value, the mass flowrate of separated pre-flash vapor increased to 8.38 ton/hr. and, the liquid product of the pre-flash drum reduced to 89.62 ton/hr. Also, the furnace duty reduced from 3.85 $*10^7$ KJ/hr. in the main case to3.53$*10^7$ KJ/hr. in retrofitted case and, the pump power is decreased from 44.6kW to 39.25 kW in the retrofitted case. Therefore, the optimum pre-flash drum pressure was preferred to be 1.5kg/cm^2.

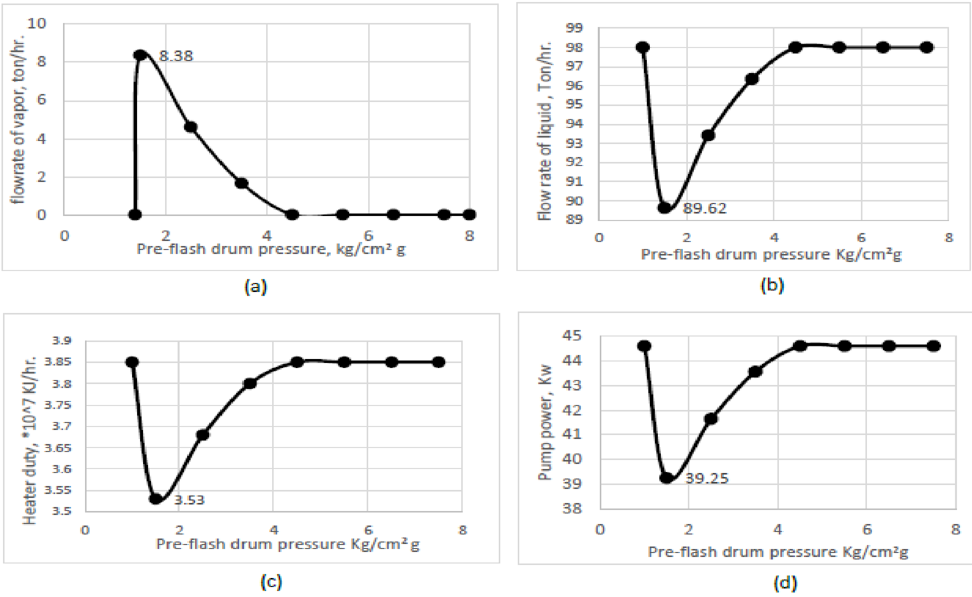

Figure 11: Optimum values of the pre-flash drum vapor flowrate (a), liquid flowrate (b), heater duty (c), and pump power (d) at the optimum value of the pre-flash drum pressure

4.4.2 Pre-flashed vapor feed tray to ADC

The feed tray of pre-flashed vapor in ADC is also an important parameter for efficient energy management**.** According to results from HYSYS shown in Table 5, the effect of varying the feed tray of pre-flashed vapor from tray 1 to tray 22 in ADC on the mass flowrate of products, and condenser duty was studied. The pre-flash drum pressure is taken as 1.5 kg/cm^2 and the heater duty is 3.53*10^7 KJ/hr.

The optimum feed tray is the tray at which the highest profit is achieved. The operating cost of fuel gas burned in the furnace is assumed to be constant but the condenser duty and the product mass flow will vary with the variation of feed tray pre-flashed vapor. The profit is calculated by subtracting the operating cost of cooling sea water (C_c, \$/hr) required in the condenser (condenser duty cost) from the selling value of the products (S_p, \$/hr) using Equations from (1) to (4) [16].

Table 5: Result from the simulation feed tray of pre-flashed vapor variation in ADC						
Feed tray in ADC	Condenser duty (*10^7 KJ/hr.)	Mass flowrate of products, m_i (Ton/hr.)				
		Off gas	LN	Kerosene	AGO	Fuel oil
1	2.7572454	1.07	23.48	5.24	12.27	56.02
2	2.7486022	1.10	23.94	5.20	11.29	56.55
3	2.6128042	1.10	23.94	5.20	11.29	56.55
4	2.4897654	1.12	23.86	5.24	11	56.88
5	2.4714647	1.11	23.86	5.29	11.27	56.57
6	2.4714647	1.11	23.86	5.31	11.31	56.51
7	2.4704751	1.11	23.86	5.31	11.31	56.50
8	2.4700630	1.11	23.86	5.32	11.31	56.50
9	2.4698996	1.11	23.86	5.35	11.26	56.52
10	2.4671059	1.11	23.85	5.34	11.27	56.51
11	2.4670541	1.11	23.85	5.39	11.20	56.54
12	2.4677475	1.12	23.84	5.64	10.80	56.70
13	2.4675673	1.10	23.89	5.60	10.80	56.70
14	2.4673748	1.11	23.91	5.58	10.80	56.69
15	2.4672813	1.10	23.93	5.57	10.81	56.69
16	2.4675381	1.10	23.94	5.56	10.81	56.69
17	2.4660425	1.10	23.94	5.56	10.81	56.69
18	2.4651915	1.09	23.95	5.54	10.82	56.69
19	2.4656178	1.09	23.98	5.51	10.82	56.69
20	2.4671687	1.07	24.06	5.43	10.85	56.68
21	2.4691832	1.05	24.18	5.31	10.89	56.66
22	2.4716550	1.03	24.30	5.20	10.91	56.65

$$V_c(\text{cooling water volume flowrate}, m^3/hr) = \frac{Q_c(\text{condenser duty})}{C_p\ \Delta T\ \rho_w} \quad (1)$$

Where for water: C_p=3.935 Kj/kg °C, ΔT=10 °C ,ρ_w=1025 Kg/cm^3

$$C_c\left(\text{cooling water cost}, \frac{\$}{hr}\right) = C_o(\text{seling price of cooling water}, \$/m^3) * V_c \quad (2)$$

Where C_o= 0.0197 \$ / m^3

$$S_p(\text{products value}, \$/hr) = \sum S_{p,i} * m_i \quad (3)$$

Where $S_{p,i}$ is the selling price of each product, and it is listed in Table 6, m_i is the product flowrate, ton/hr

$$\text{Profit}\ \left(\frac{\$}{hr}\right) = S_p - C_c \quad (4)$$

The profit is calculated and described in Figure 12. As illustrated, the highest profit (283.616*10^6 $/yr)is at tray 22 (top tray). The optimum data determined for the pre-flash drum is illustrated in Table 7.

Table 6: The real sale price of products					
Product	Off-gas	LN	Kerosene	AGO	Fuel oil
Sale price (SP i), $/ ton	356.5	551	429.6	429.6	267.34

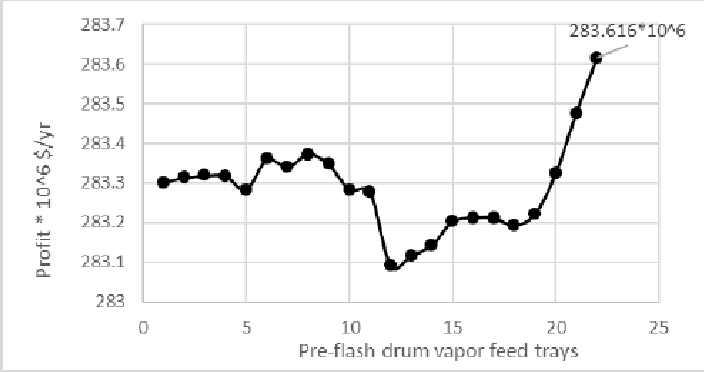

Figure 12: Profit calculations at different pre-flash drum vapor feed trays to the ADC

Table 7: Optimum-operating conditions of Pre-flash drum	
Parameter	
Temperature o C	155
Pressure Kg/cm^2	1.5
Pre-flashed vapor tray in ADC	22 (first tray from top of the ADC)

4.3 Economic study

The heating duty, condenser duty and, pump power of the CDU are taken from energy streams in both of main case and retrofitted case at the optimum operating conditions. Table 9 presents the energy consumption and the product flowrate for the main case and the retrofitted case. The operating cost of cooling sea water required in the condenser is calculated by Equations (1) and (2). The product sale value for each case is calculated by Equation (3). The operating cost of fuel gas burned in the furnace is calculated by Equations from. (5) to (7).The operating cost of electricity for motor pump power for each case is calculated by Equation (8). The total operating cost for each case is calculated by Equations (9) [16]. The total profit comparison for main and retrofitted cases is shown in Table 8. With fixing cost, flowrate of crude oil, steam in each case and, using the operating hours 7920 hour per year, the net profit for the main and retrofitted cases are 281,333,448, 281,937,823.2 $/yr respectively. The profit increased in the retrofitted case by 604,375.2 $/Y.

Table 8: Energy consumption and product mass flowrate for the main and retrofitted cases

Case	Furnace duty (*10^7 KJ/hr.)	Pump power [kW]	Condenser duty (*10^7 KJ/hr.)	Mass flowrate of products (Ton/hr.)				
				Off gas	LN	Kerosene	AGO	Fuel oil
Main case	3.85	-	2.8	1.05	24.1	5.27	10.82	56.85
retrofitted case	3.53	39.25	2.47	1.03	24.3	5.2	10.91	56.65

$$Q_{fuel}\left(\frac{kj}{hr}\right) = \frac{Q_{absorbed}}{\eta_{furnace}} \quad (5)$$

Where η furnace =90%

$$\mathrm{m_o(fuel\ gas, kg/hr)} = \mathrm{Q_{fuel}} / \mathrm{LHV} \quad (6)$$

Where LHV =48869 Kj/kg

$$\mathrm{C_{furnace}}\left(\frac{\$}{\mathrm{hr}}\right) = \mathrm{C_{o,fuel}} * \mathrm{m_o} \quad (7)$$

Where $C_{o,fuel}$= 0.261 $/kg

$$\mathrm{C_{electricity}}\left(\frac{\$}{\mathrm{hr}}\right) = \mathrm{C_{e,fuel}} * Power_{pump} \quad (8)$$

Where $C_{e,fuel}$ = 0.0611 $/kWh, $Power_{pump}$ = 39.25 kWhr.

$$\mathrm{cost_{operating}}\left(\frac{\$}{\mathrm{hr}}\right) = \mathrm{C_{furnace}} + \mathrm{C_{electricity}} + \mathrm{C_c} \quad (9)$$

$$\mathrm{Total\ Profit} = \mathrm{S_p} - \mathrm{cost_{operating}} \quad (10)$$

Table 9: Total profit comparison for the main and retrofitted cases

Case	Main case	Retrofitted case
Value of product sale, Sp ($/hr)	35,763.97	35,822.16
Fuel gas cost ($/hr)	228.4	209.47
Cooling water cost ($/hr)	13.67	12.07
Electricity cost ($/hr)	-	2.4
Total operating cost ($/hr)	242.07	223.95
Decrease in operating cost ($/hr)	18.12	
Saving percentage of operating cost %	7.49	
Profit (($/hr. *7920) ($/Yr)	281,333,448	281,937,823.2
Increasing in profit ($/Yr)	604,375.2	

The capital cost is evaluated using the Aspen Process Economic Analyzer in aspen HYSYS V11. The retrofit capital cost includes two parts new pre-flash drum and a new pump. This new equipment is sized and economically evaluated. The equipment and installed costs of the newly added pre-flash drum and new pump are summarized in Table 10. The total capital cost is calculated as the sum of equipment and installed costs for the pre-flash drum and pump. The total capital cost equals $310,598.35.

Table 10: Capital cost of new equipment in retrofitted case

Equipment	Equipment cost [$]	Installed cost [$]	Capital cost [$]
Pre-flash drum	38,574.15	163,176.3	201,750.45
Pump	27,975.8	80,872.1	108,847.9

The Payback period = Total capital cost / Increase of total profit

= 310,598.35 / 604,375.2

= 0.514 Y.

5. Conclusion

The retrofit of an existing atmospheric distillation unit has been considered in this paper to reduce the power consumption of the unit in case of dealing with the light crude oil type. Retrofit is based on implementing a pre-flash drum and pump for the existing unit. Maintaining pre-flash pressure at 1.5kg/cm^2 is very important to increase the vapor product separated from the pre-flash drum. Selection of the feed tray (top tray) of pre-flashed vapor in ADC is optimum to decrease the operating cost and increase the profit. The retrofitted unit can ensure design capacity (125 Ton/hr.).The annual increase of profit in the new retrofitted atmospheric distillation unit is $ 604,375.2 but with a capital cost increase of $ 310,598.35 as a result of the total capital cost of the new pre-flash drum and pump.7.49% operating cost saving was achieved in the retrofitted case with less than6monthspayback period.

Abbreviations

ADC	Atmospheric Distillation Column
ADU	Atmospheric Distillation Unit
AGO	Atmospheric Gas Oil
CDU	Crude Distillation Unit
HEN	Heat Exchange Network
HN	Heavy naphtha
LN	Light naphtha
SS	Stripping Steam

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