Optimum Pressure Distribution in Design of Cryogenic NGL Recovery Processes

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ABSTRACT: *This paper introduces an effective parameter for optimum design of integrated cryogenic NGL recovery plants. The process fluid pressure is an important factor which can affect the plant characteristics. A cryogenic liquid recovery plant was selected as a case study. The influence of different values of pressure drop in various equipments on the quality and quantity of the process outputs were analyzed. The results show that the product specification, quantity and operating costs of the plant are important parameters which a balance between them will determine the optimum pressure distribution in the process. The plant wide net profit can be used as an objective for obtaining the optimum pressure distribution. The products' price and operating costs change due to economical and political situations. So the optimum pressure distribution in a process can be changed based on the plant wide net profit in various situations.*

KEY WORDS: *Natural Gas Liquids (NGL), Process; Optimization, Pressure***.**

INTRODUCTION

The production and consumption of natural gas is on the rise throughout the world as result of its wide availability, ease of transportation and use, and clean-burning characteristics. The emerging commodity nature of natural gas, however, has created increasingly tighter competition among natural gas processors for processing rights, and resulted in increasingly narrow operating margins between the processing cost and the recovered liquids which can be sold [1-3].

Within the liquids recovery section of the facility, there are both operating cost and operating flexibility issues that directly impact the processing cost. Increase in the price of energy sources and economical problems have caused cryogenic natural gas liquid recovery plants to be more complex and efficient. In other words, the new generation of NGL plants is created based on decreasing the fixed and operating costs of the plant for specific output. There are some process parameters which affect the power consumption and product quality and quantity [4-6]. There are some fundamental procedures that designers try to use them to propose the most optimum and efficient process:

- Recycling the cold output process streams from the separation section to the process.

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-Decrease the operating costs of the refrigeration cycle by supplying a portion of required duty via cold process streams.

- Decrease the size of the refrigeration cycle by supplying a portion of required refrigeration via reduction of process streams pressure. With increasing the recoverable refrigeration from the cold process streams less external refrigeration will be required. The references [7-9] show the works have been done in this area.

All of the above said procedures tend to shift the process configurations to the integrated one for the sake of decreasing the fixed and operating costs. Adjusting the operating condition of an integrated process configuration is another method which can improve the plant performance. In this level of design, there are some parameters which can increase or decrease the plant costs and outputs. *Mehrpooya et al.* [10] introduced a new parameter which can evaluate the degree of integration of the cryogenic liquid recovery process configurations. This parameter can evaluate the degree of integration based on the recovered refrigeration from the process streams against the required refrigeration which is gained by different sources.

Pressure plays a major role in gas processing, as it moves gas from the field, through the gas plant, and into the sales gas line. Pressure provides the source for cooling the gas to low temperatures.

Shen et al. [11] discussed about high pressure natural gas pipelines. It showed that a small scale LNG plant can be installed between transmission pipeline and distribution pipeline. Energy normally lost when natural gas is depressurized at city gates, it can be conserved using turbo expansion technology, thus improving energy efficiency and costs.

A study on the capital and operating alternatives in an ethane extraction plant was done by [12]. Cold tank pressure, recompressed discharge pressure and demethanizer operating pressure were three of selected decision variables in that work. The optimization results showed that the plant wide net profit, how affected by theses decision variables.

In [13] a turbo-expander plant was optimized by an improved genetic algorithm. Operating pressure of the flash drum, output pressure of the expander and top pressure of the distillation column were three of selected variables. In other word they tried to select the optimum pressure distribution by an optimization method. But the effect of column operating pressure on the specification of the products was not cited. Also selected bonds in that work didn't let the pressures in different points encounter. Column operating pressure was one of the decision variables in the reference [14]. The effect of this parameter on the cost objective function was discussed in that work.

Panjeshahi & Tahouni [15] developed a new procedure for pressure drop optimization in debottlenecking. This procedure enables the designer to study pump and/or compressor replacement whilst at the same time optimizing the additional area and operating cost of the network. It deals with the problem of optimal debottlenecking of heat exchanger networks considering minimum total cost. *Mehrpooya et al.* [6] introduced a method for optimum design of integrated liquid recovery plants by a variable population size genetic algorithm. They showed that the flow rate, pressure and temperature of the process fluid streams are determining factors which should be tuned in order to find the optimum condition.

In this work we tried to show the effect of the place and the location of the pressure drop on the performance of cryogenic natural gas plants. The equipments that the pressure drop occurrence in them can affect the process performance are introduced. The consequences of the pressure drop in specific equipments on the process performance are discussed. In the other hand this study introduces the pressure distribution concept. This concept can help the designers to concentrate on the pressure as a design tool and also use this concept in order to optimize the process operation.

PRESSURE DROP IN CRYOGENIC NATURAL PLANT EQUIPMENTS

Demethanizer

In all NGL recovery processes, one of the final steps in the plant is the production of the desired liquid product by use of a fractionation column. This column produces the specification product as a bottom product with the overhead stream being recycled to the process or sent out of the plant as residue gas product [16]. Processes employing a demethanizer column separate methane and other more volatile components from ethane and less volatile components in the purified gas stream. [17]. An NGL recovery plant design is highly dependent on the operating pressure of the distillation column.

At the medium to low pressure, i.e. 400 psia or lower, the recompression horsepower requirement will be so high that the process becomes uneconomical. However, at higher pressures the recovery level of hydrocarbon liquids will be significantly reduced due to the less favorable separation conditions.

J-T Expansion

One of the key parameters in the recovery of ethane and heavier products is effect of the extraction on the heat content of the residue gas. The use of the Joule-Thomson (J-T) effect to recover liquids is an attractive alternative in many applications. With appropriate heat exchange and large pressure differential across the J-T valve, cryogenic temperatures can be achieved resulting in high extraction efficiencies [17].

Turbo-expander

A turboexpander generates the deep, low-temperature refrigeration industrially used for gas separation and liquefaction. It does so by the mechanism of constant entropy expansion, together with the production of power (a byproduct) [18]. Unlike J-T expanders, they perform work during the process. Whereas J-T expansion is essentially an isenthalpic process, an ideal, thermodynamically reversible turbo-expander is isentropic. Turbo-expansion provides the maximum amount of heat removal from a system for a given pressure drop while generating useful work [16].

EFFECT OF PRESSURE DISTRIBUTION ON THE PLANT PERFORMANCE

As explained in the previous sections the J-T valves and turbo-expanders are used for supplying a portion of required refrigeration in the plant. In advanced integrated liquid recovery processes, the plant wide net profit is more sensitive to the pressure drop rather than the previous configurations. In other words, with changing the pressure in the specific points of the process by J-T valves the temperature of some streams changes, and consequently the separation efficiency will be changed. Using the multi stream heat exchangers causes different streams from different parts of the plant and the refrigeration cycle to exchange their heat. Therefore in such integrated plants the effect of pressure drop in a specific point may change the process performance due to its multi dimensional effect.

Input feed stream pressure to the plant is a determining factor. The process fluid stream temperature decreases by passing through the J-T valves and turbo-expanders. The pressure drop in the mentioned equipments determines the amount of the output stream temperature. There are several J-T valves in a liquid recovery plant which are used for supplying a portion of the required refrigeration. But pressure of the input feed stream is constant and the column operating condition depends on the liquid recovery in the process. So the pressure difference between the feed and column operating pressure is the allowable pressure drop in the equipments before the demethanizer. This available driving force can be used in different parts of the process. Also the amount of the pressure drop is another variable which can affect the separation condition. The column products are the other cold source and these streams will be cooler if they flow to the expansion devices. The more pressure drop in the J-T valves, the cooler streams flows to the heat exchanger, and consequently the better separation condition will be gained. The column gas product is used for cooling the input feed stream before injection to the gas pipeline. Nonetheless the gas pipeline operating condition (the temperature and the pressure) is definite so the pressure and temperature of the plant gas product should be changed to the pipeline condition by compressors and air coolers. Therefore the operating cost of the plant is a function of the amount of the pressure drop in the J-T valves.

Finally, the sequential effect of the points where the pressure drop occurs on the other pressure sensitive points reveals the concept of the distribution. In such a situation the goal would be the most optimum pressure distribution.

Effect of pressure drop on the operating costs of the plant

Air cooler

Air-cooled exchangers are sized to operate at warm (summer air temperatures). One way to control the amount of cooling is by varying the amount of air flowing through the tube section [17]. This equipment is used for decreasing the refrigerant temperature and reducing the temperature of the gas product to the pipeline gas temperature. As the pressure drop in the equipment decreases more shaft work will be needed in the compressors section. Consequently the output temperature of the stream increases. So for an existing air cooler, more air flow should be consumed. In such situations, with increasing the fan power the air flow increases and the output temperature decreases. So the plant operating cost increases.

Compressor

Gas and refrigeration compressors typically are the largest capital expense in the construction of a new gas processing plant. They account for up to 50 to 60% of the total installed cost of the facility. They also tend to have the largest maintenance expense in the facility [16].

Effect of pressure drop on the products of the plant

Liquid product

Typically, modern gas processing facilities produce a single ethane plus product (normally called Y-grade) which is often sent offsite for further fractionation and processing. The degree of fractionation which occurs is market and geographically dependent. The ethane plus volume flow is considered as the liquid product of a liquid recovery plant. The price of this product may changes in different places. Also variations of the oil price can affect the price of this product. Hence the performance of a liquid recovery plant is a function of the products prices. With changing the pressure distribution in a plant it is possible to change the NGL volume flow.

Gas product

The other major consideration in the evaluation of NGL recovery options is the specification of the sales gas. Sales specifications are usually concerned with a minimum Higher Heating Value (HHV) of the gas. Removal of liquids results in gas “shrinkage” and reduction of the HHV. This shrinkage represents a loss of revenue for the gas sales which must be considered in the economics of an NGL recovery plant. The recovery level of the ethane and heavier components is then limited by markets, cost of recovery, and gas value [17].

Effect of pressure drop on the plant wide net profit

Plant wide net profit is the final criterion which determines the optimum pressure distribution. It can be defined as: annualized revenue of the gas product; annualized revenue of the liquid product and annualized operating cost. However the liquid recovery and process limitations should also be considered. As explained before the pressure variations of some places in which the process are sensitive to, causes various changes. It can increase the products in addition to increases the operating costs. So it is the profit that determines the best pressure distribution. The economical and other motivations may change the amount of profit, so they are not constant parameters.

A CASE STUDY

Process description

A retrofitted currently in operational NGL recovery unit is selected as a case study. The specification of the primary unit can be found in [19]. The specifications of this plant are represented in the Tables 1 & 2. The errors in Table 2 show the deference between the real data (NGL1300 plant in Iran) and the simulation results.

Fig. 1 shows the sub-flow sheet of the unit in more detail. A brief description about the plant is followed.

The inlet gas stream comprises clean, filtered, and dehydrated natural gas which has been treated in previous units. Stream1 (inlet gas) is mixed with the stabilization liquid product (Stream 2) and directed to the multi stream heat exchanger (MSHEX 1). The feed stream temperature is reduced to -42° C by this heat exchanger.

The outlet gas stream flows to the cold separator (V-1); liquid hydrocarbons (12) flow to the demethanizer. Before entering the column, the temperature decreases by a J-T valve (VLV-3) to -52°C. A portion of the V-1 gas product flows to the MSHEX-1. Then it enters the column at -48°C. A propane refrigeration cycle supply required refrigeration of the process, as well as the J-T valves and turbo-expander EX-1. Streams No. 60 & 61 which evaporates in the MSHEX-1 chill the input feed streams. More information about the propane refrigeration cycle can be found in the works [19-20].

The overhead vapors produced in the demethanizer flow to the MSHEX 2. The MSHEX 2 acts as a refrigeration cycle condenser. It chills the pressurized refrigerant stream (45). Besides, this heat exchanger plays the role of reboiler demethanizer, so its performance affects the performance of the tower and refrigeration cycle simultaneously. The tower bottom product is the liquid product of the plant (NGL product).

A portion of the gas leaving the V-1 separator is sent to the Feed EX-1 turbo-expander where it is expanded

Table 1: The properties of Feeds and products.

Composition & Conditions	1	Error %	2	Error %	NGL Product to polishing	Error %	Lean Gas to Lean Gas Header	Error %
H_2O	5.00×10^{-3}	0	8.49×10^{-8}	0.05	2.37×10^{-5}	0.05	1.30×10^{-5}	0
H_2S	2.65×10^{-6}	1.05	5.00×10^{-5}	0.99	7.57×10^{-6}	0	2.30×10^{-5}	0
CO_2	2.12×10^{-6}	0.66	2.21×10^{-8}	0.7	1.44×10^{-6}	0.2	2.26×10^{-5}	
C1	0.7146	1.66	9.97×10^{-10}	1.2	0.025	0	0.8543	0.1
C2	0.1435	0	1.99×10^{-4}	0.02	0.2774	2	0.1102	0
C3	0.0865	0.03	0.1546	0.04	0.3546	0.3	0.0296	1
IC4	0.0102	0.06	0.0603	0.22	0.0546	0.4	1.70×10^{-3}	0.32
NC4	0.0261	0.75	0.2234	0.76	0.1527	0.05	3.07×10^{-3}	0.41
IC5	5.42×10^{-3}	0.4	0.1074	0.94	0.0399	0.006	2.93×10^{-4}	0.08
NC5	5.31×10^{-3}	2.23	0.1311	2.24	0.0422	0.003	2.20×10^{-4}	0.01
NC6	2.19×10^{-3}	0.34	1.1383	0.33	0.0267	0.002	3.42×10^{-5}	0.008
C7+	1.15×10^{-3}	0	0.1827	7.2	0.026	1	7.29×10^{-6}	0.008
DEA	9.26×10^{-8}	0	0	0	5.06 E $^{-7}$	0	3.13×10^{-15}	0
Temperature (°C)	60.0595	1	62.045	0.002	42.5	0.001	59.1764	0.01
Pressure (kPa)	3700	0.05	3490	0.08	3940	0	3410	1
Rate (kmole/h)	8698.8818	1.1	172.2759	0.08	1593.8229	0.01	6950.729	0.55
Molecular Weight	22.877		71.2353	0	47.3613	0		0
Mole Fraction Liquid	0	0	1	0	1	0	1	0
STD LIQ Rate (m^3/DAY)			840		439.3			

Table 2: Operating conditions of the points under consideration.

Streamname	A1	A2	A3
Flow (kmol/h)	1900.00	4924.43	4626.60
Temperature (°C)	-59.97	-76.57	-50.60
Pressure (kPa)	1800.00	500.00	3000.00

to the demethanizer's operating pressure of approximate 20 bar, thus providing the process with low temperature refrigeration duty.

The gas which leaves the top of the demethanizer after being heated in the MSHEX 2 is fed to the pipeline gas. A portion of the tower gas product is mixed with a portion of the turboexpander and enters to MSHEX 1 after passing from a J-T valve (VLV-6). VLV-6 decreases A1 temperature to -76 °C.

The streams leaving the demethanizer are very important because they are very cold. Such low temperature streams enter multi stream heat exchangers and chill the feed stream before flowing to the column. More recovery levels are gained by the lower temperature separation conditions. So a portion of the required refrigeration is supplied by these streams. These cold streams become cooler by decreasing their pressure and consequently more liquid hydrocarbon will be gained. Alternatively the required refrigeration can be decreased by such cooler streams. But when the pressure decreases, more power is consumed for supplying the needed pipeline pressure. Therefore a balance should be performed between the amount of the NGL product and plant costs.

The points which the process performance is sensitive to their pressure

Based on the consequences of changing the process fluid pressure in different locations of the flowsheet, it was cleared that there are four points which the process is sensitive to. In other words, the NGL plant performance changes with changing their pressure. The pressure of the streams A1, A2, A3 and operating pressure of the demethanizer column are the ones which can affect the process performance.

- As can be seen from Fig. 1p ressure of stream A1 is controlled by the VLV-7 valve. This stream is a portion of the demethanizer gas product, so it has lower temperature towards the other process streams. With increasing the pressure drop in the VLV-7, the A1 stream temperature decreases. The performance of the MSHEX 2 multi stream heat exchanger and consequently the demethanizer is affected by this pressure changed. Therefore the product flow rate and quality change as the pressure changes. The variation of the power needed for the plant is the other consequence of changing the A1 stream pressure. The C-5 compressor and A-3 air cooler are responsible for changing the stream 19 condition to the pipeline operating condition.

- The A2 stream is used for supplying a portion of the required refrigeration by MSHEX 1. The temperature of Stream No. 6 is very important because of its instant effect on the liquid product of the plant. The lower the temperature of stream No. 6, the more liquid hydrocarbon flows to the demethanizer. Such change also can influence the column performance. The pipeline operating condition is the other problem which should be considered through variations of the stream No. A2 pressure.

- The output stream temperature of the EX-1 turbo-expander is a function of its pressure. Like the A1 & A2 streams the temperature decreases as the pressure decreases. But in this case, as the output stream pressure decreases, the generated shaft work in the EX-1 increases. A portion of EX-1 flows to the demethanizer so it can affect the column performance directly. The VLV-6 is located after EX-1, therefore the A3 stream pressure has a sequential effect on the stream No. A1 pressure.

- The consequences of variation of the demetahanizer operating pressure were described in the 2.1 section. But in advanced liquid recovery plants, the influences of column operating pressure may differ from the basic ones because of the integrated process nature.

Simulation for the system

Simulation of the entire plant was carried out using HYSYS simulator and PRSV equation of state for calculation of the thermodynamic properties.

RESULTS AND DISCUSSION

Effect of the pressure changes on the plant characteristics

For evaluating the influences of pressure variations on the performance of the NGL plant, the pressure of the sensitive points were changed in an allowable bond. Next, their effects on the plant outputs and operating costs were analyzed. The required power in the plant was supposed to be the compressors, the turbo-expander shaft work and the air coolers fan power.

The product specifications which contain gas product heating value, NGL product volume flow and the recovery percent of the ethane and propane were considered for evaluation.

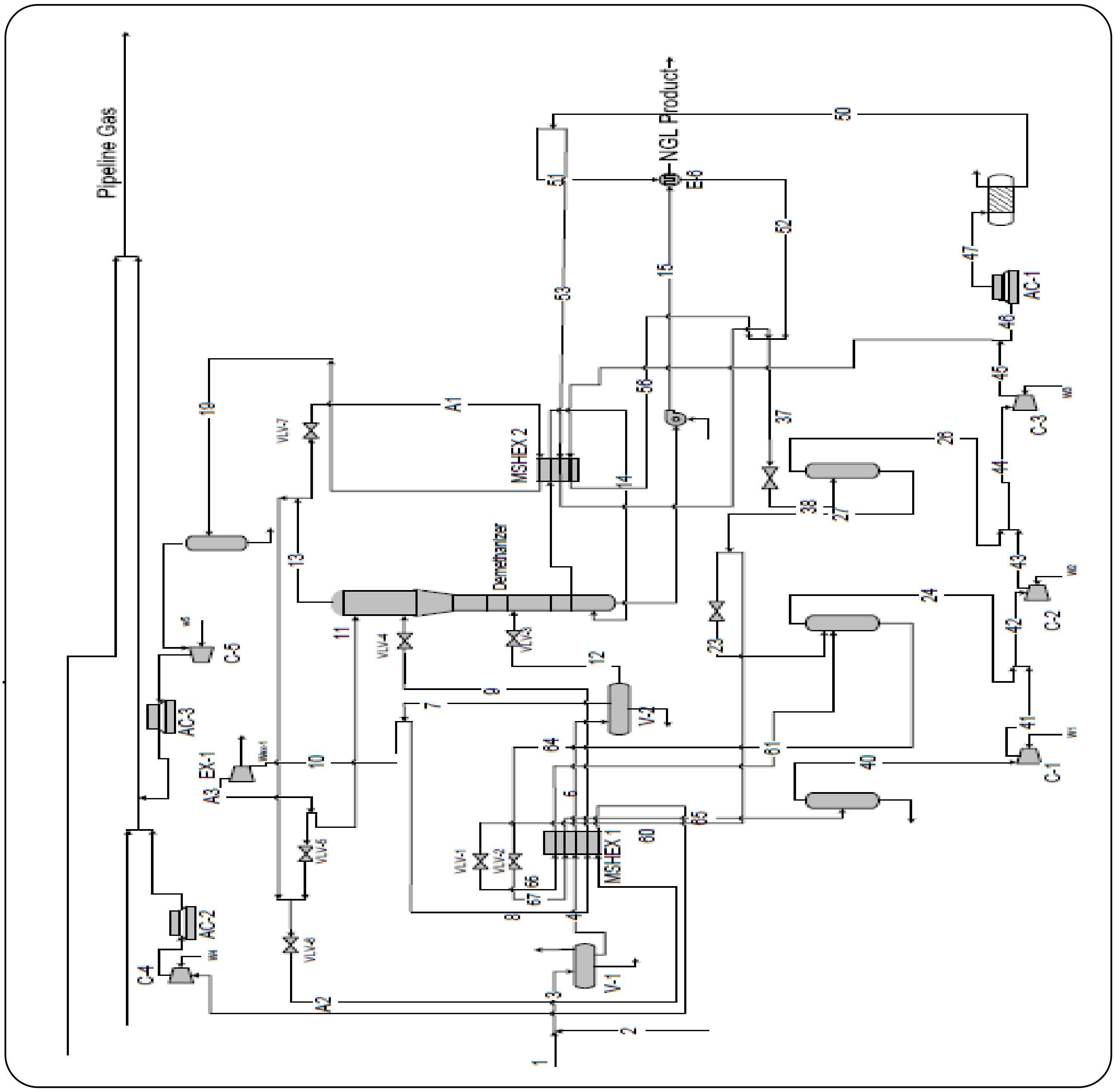

Fig. 1: Main process flow block diagram of C_2^+ Recovery plant.

Figs. 1-10 show the plant behavior through the pressure changes of the places under consideration. They are plots with multiple x- and y- axes.

Fig. 2 illustrates the relationship between the ethane recovery and the streams No. A1 & A2 pressure. With increasing the mentioned stream pressures, ethane recovery decreases. Changing the separation condition by changing the temperature levels in MSEHX 1 and MSHEX 2 is the reason of such behavior. The A1 stream pressure affects the MSHEX 2 performance. At pressures more than 800kPa ethane recovery decreases due to increase in A1 temperature. Sudden reduction of A1 temperature causes ethane recovery variations which display such behavior at pressures less than 800kPa.

Ethane recovery decreases as A2 pressure increases. Effect of A2 pressure on the V-2 hydrocarbon liquid output causes ethane recovery to decrease when the temperature of the input stream to V-2 increases.

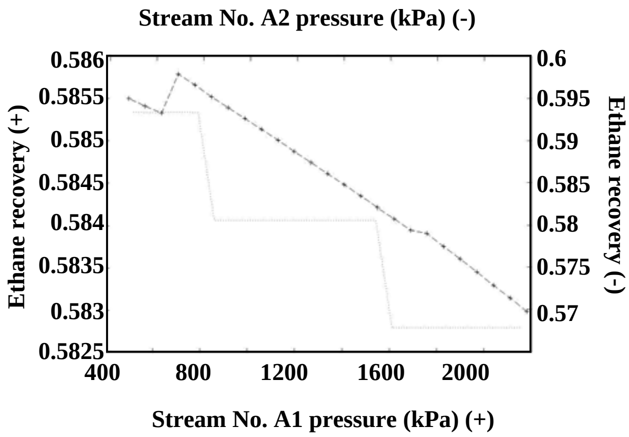

Fig. 2: Variations of ethane recovery with change in the A1& A2 stream pressures.

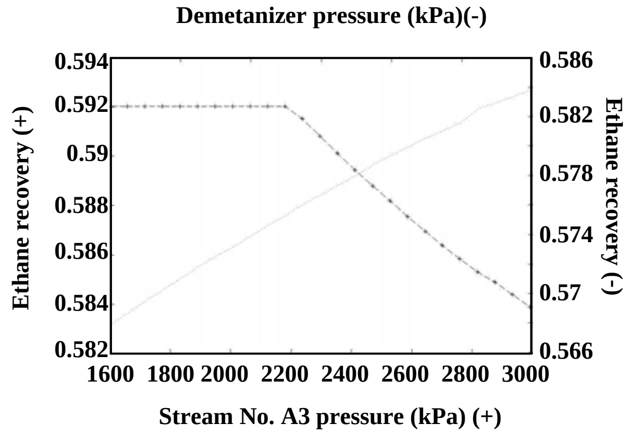

Fig. 4: Variation of propane recovery against streams No.A1& A2 pressure.

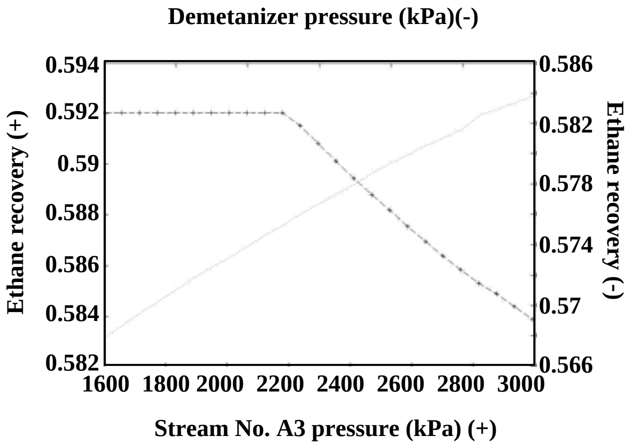

Fig. 3: Ethane recovery versus stream No.A3 pressure and the column operating pressure.

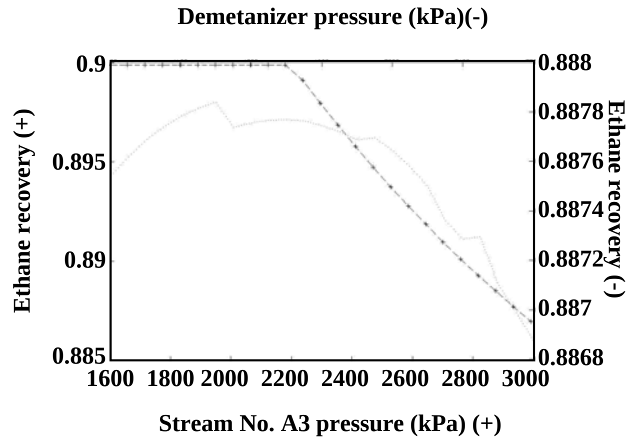

Fig. 5: Variation of propane recovery against stream No.A3 pressure and the column operating pressure.

The ethane recovery decreases at two levels, 800& 1600kPa, respectively. This is due to adjusting the stream No.7 temperature, based on the A1 temperature reductions.

Fig. 3 shows the behavior of ethane recovery versus stream No.A3 pressure and the column operating pressure. Increasing A3 pressure does not affect the ethane recovery up to 1850 kPa. At pressures more than 1850 kPa the ethane recovery reduces linearly. It shows that changing the column input operating conditions (temperature and pressure) affects the component recoveries. Increasing the ethane recovery through increasing the column pressure is the other noticeable point.

Ethane recovery decreases as the column operating pressure increases unlike it was expected. Increasing the separation condition temperature may rationalize such a trend.

The variation of the propane recovery is plotted against the pressure of streams No. A1& A2 in Fig. 4. The trends of decreasing the propane recovery through increasing the A1 & A2 stream pressure are similar to the trend of ethane recovery reduction. The reduction in propane recovery is due to increase in the stream temperature because of increase in its pressure.

Fig.. 5 illustrates the relationship between propane recovery and stream No.A3 pressure, and the column operating pressure. Enhancing the A3 stream pressure has a similar effect on propane recovery. This means that the propane recovery does not change up to 1850 kPa. Next, it decreases as the A3 stream pressure increases. But in the case of the column operating pressure, unlike the ethane

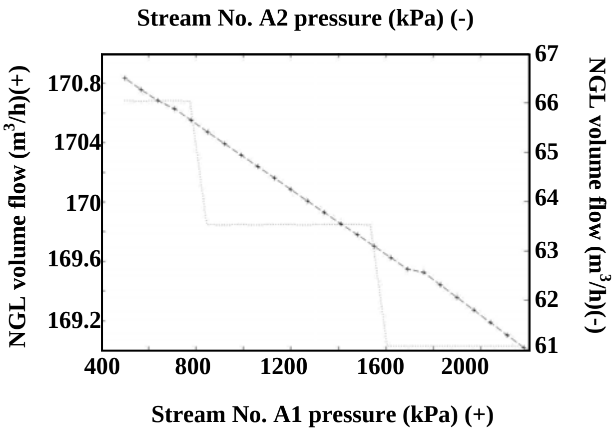

Fig. 6: NGL volume flow (m^3/hr) versus streams No.A1& A2 pressures.

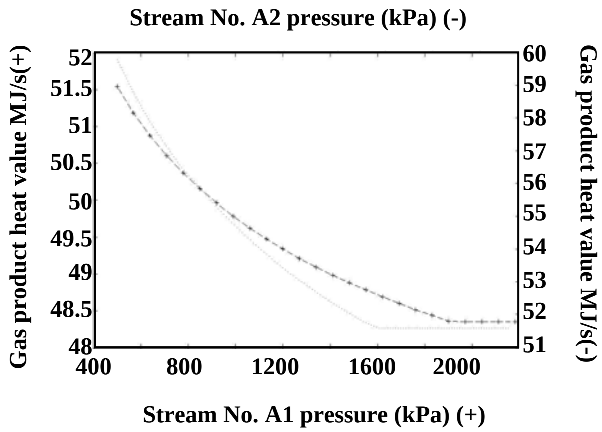

Fig. 8: Variation of the gas product heat value (MJ/s) against streams No.A1& A2 pressure.

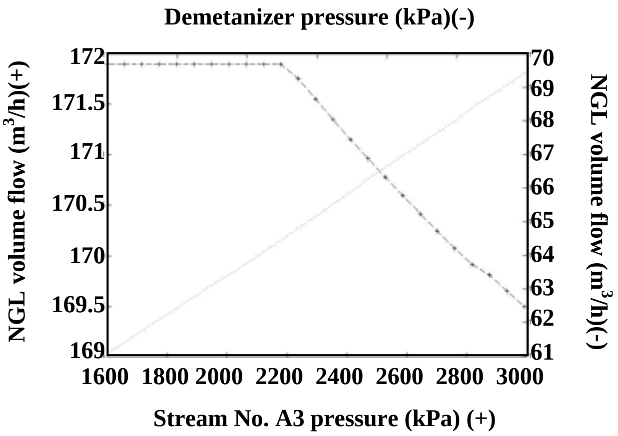

Fig. 7: NGL volume flow (m^3/hr) versus stream No.A3 pressure and the column operating pressure.

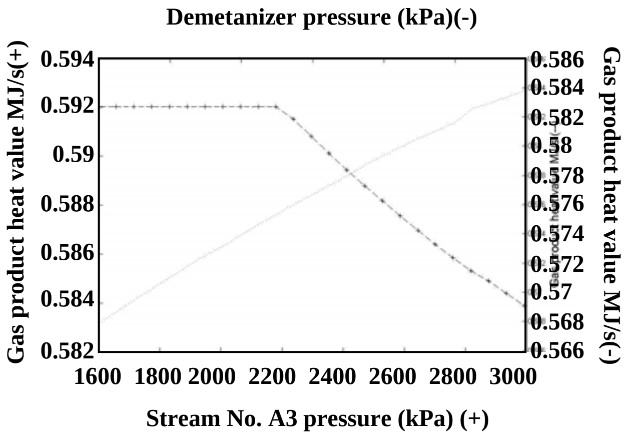

Fig. 9: Heat value against stream No.A3 pressure and the column operating pressure.

recovery, as the column operating pressure increases, propane recovery is enhanced up to 1950kPa. Next, it decreases nonlinearly.

Fig. 6 shows the behavior of NGL volume flow (m^3/h) versus streams Nos. A1 & A2 pressures. As it was expected, the NGL product decreases as the separation temperature increases. The NGL volume flow is reduced linearly as the A1 stream pressure was increased. But the NGL volume flow reduction occurs in three levels. This figure shows how the liquid product volume flow can be increased by changing the streams pressure.

Fig. 7 illustrates the relationship between the NGL volume flow (m^3/h) versus stream No.A3 pressure and the column operating pressure. The NGL volume flow is reduced through enhancing the column operating pressure.

HHV (Higher Heating Value) is considered as the heat value of the plant gas product.

Variation of the gas product heat value (MJ/s) is plotted against the streams Nos. A1 & A2 pressure in Fig. 8. The gas product heat value decreases as the pressure of these streams increases. The composition and the flow rate variations of the stream No. 20 affect the heat value of the plant gas product. Decreasing the ethane and propane recovery due to increasing the A1& A2 stream pressures is one of the reasons which caused such behavior.

In Fig. 9 the gas product heat value is plotted against stream No. A3 pressure and the column operating pressure. As can be seen the gas product heat value is affected. Reduction of the propane and ethane recovery and NGL volume flow cause the gas heat value to increase.

Table 4: The effect of pressure distribution on the plant performance.

	Initial value	Distribution1	Distribution2	Distribution3	Distribution4	Distribution5
A1 pressure	1700.0	1699.0	1704.0	1689.5	1733.0	1733.2
A2 pressure	1200.0	510.0	500.2	498.3	499.2	500.0
A3 pressure	2700.0	1800.0	1780.9	1750.2	1735.5	1750.2
Clumn pressure	1950.0	1700.0	1746.2	1690.4	1738.5	1744.2
HHV (MJ/m3)	41.28	41.28	41.20	41.29	41.05	41.05
C2 recovery %	59.0	60.0	60.0	61.0	60.9	60.1
C3 recovery %	89.7	90.0	90.0	90.0	90.2	90.1
Profit ($/year)	39055000	39489971	39595000	39115571	39399600	39891000

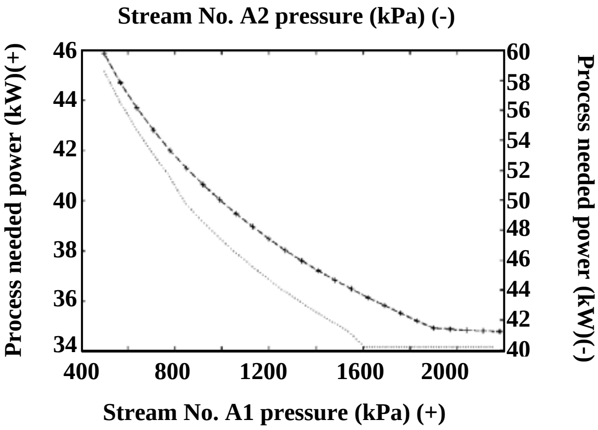

Fig. 10: Variation of the plant required power against streams No.A1& A2.pressure.

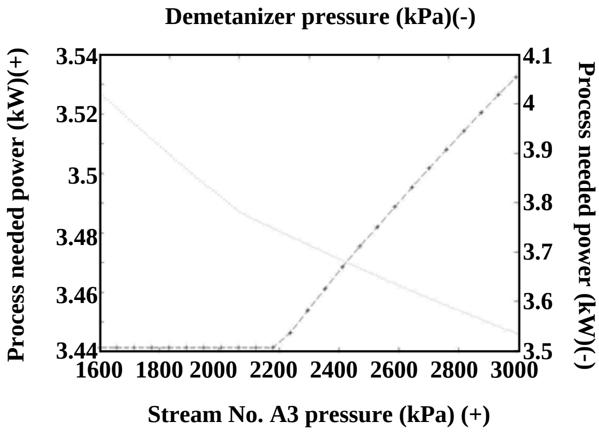

Fig. 11: Variation of the plant required power against stream No.A3 pressure and the column operating pressure.

The gas product heat value increases as the column operating pressure increases.

Figs. 10 & 11 show how the plant required power decreases if the pressure increases. The required power which includes the work of the compressors and the fan powers of the air coolers decreases if the less pressure drop occurs in the under consideration points. The generated work in the turbo-expander can affect the plant needed power. In other word as the A3 pressure increases, the generated work on the EX-1 decreases.

Plant wide net profit

When product prices, utility costs, etc. change, the plant can adapt to the new economic condition by adopting a new optimal pressure distribution.

In this part the variation of the plant wide net profit through the changes of the pressure distribution in the process is analyzed. Because of the economical and political problems and strategic values of the products it is very important to adjust the products and their specifications based on the market condition. As discussed, it is possible to change the plant products and operating costs or profit by adjusting the pressure distribution to the new condition. In this part we try to show how the profit changes with the pressure distribution and how the pressure distribution should be adjusted if a new situation happens.

The plant wide net terms change based on the new conditions. Hence, regarding the process design limitations, the pressure distribution in such plants is an effective parameter which can be set in various situations. Table 3 shows the products and power prices. Price of the natural gas depends on the several parameters, as can be seen in [21] prices may change from 2.5$/MMBTU to 11.5 $/ MMBTU

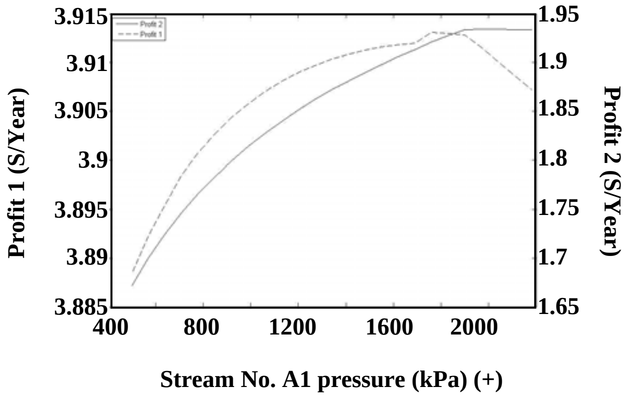

Fig. 12: Variation of the plant wide net profit against the A1 stream pressure.

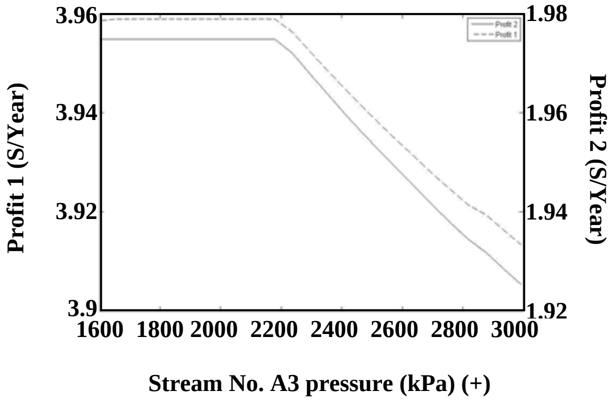

Fig. 14: The plant wide net profit against the stream No.A3 pressure.

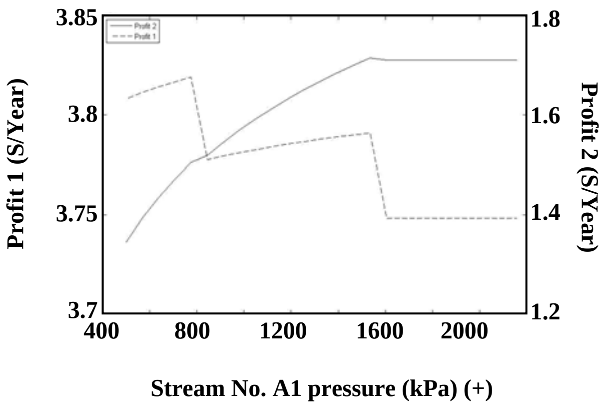

Fig. 13: The plant wide net profit against stream No.A2 pressure.

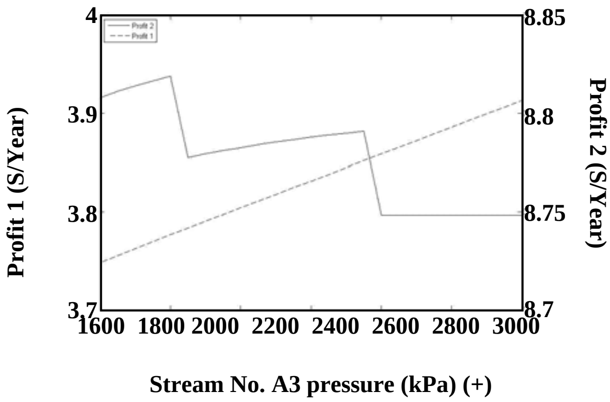

Fig. 15: The plant wide net profit against column operating pressure.

based on the time and region. Profit 1 shows the current situation and profit 2 shows the supposed condition that the product prices changes based on the past records. Profit 2 shows that the products price may decrease and consequently the plant performance will be affected.

Figs. 12-15 show how the effect of pressure distribution on the profit changes, if a new condition causes the profit terms got new values.

Fig..12 shows the relationship between the plant wide net profit and A1 stream pressure. Up to 1790 kPa profit 1 increase as A1 stream pressure increases but higher than 1790 kPa it decreases. But profit 2 shows a different behavior. It increases up to 1850 kPa and then remains constant at upper pressures.

In Fig. 13 the plant wide net profit is plotted against the stream No.A2 pressure. As can be seen, the profit 1 trend is similar to the NGL volume flow variations in Fig. 6. But it is does not seen in case of profit 2. The reason for such variation is the NGL price and its effective role on the profit.

Fig. 14. illustrates the relationship between the profits versus stream No.A3 pressure. In this case the influence of the generated power in EX-1 should be considered.

Fig. 15. illustrates the relationship between the profit and the column operating pressure. Profit 1 change in three levels as the column operating pressure increases. The style of the profit 1 variations shows how the NGL volume flow affects the profit. But by changing the prices, Profit 2 increases linearly as the column operating pressure increases.

Until now several optimization problems were defined for optimization of the cryogenic liquid recovery plants and the pressure of different points in such plants was a part of the selected decision variables. But in none of them the pressure distribution concept has not been discussed. In other words they indicated the effect of the pressure on the plant performance only in specific equipment, and the consequences of the pressure variations on the performance of the other pressure sensitive equipments was not considered. Also based on the specifications of the unit and process design consideration there is a limited pressure drop in the plant which are used as a cooling device. Consequently distributing this driving force is more important than changing the pressure in specific equipment. Changing the pressure in one point in the process (For example column operating pressure) may change the other pressure sensitive equipments performance or may obtain a potential for it to improve their performance. Thus when pressure is used as a decision variable in the unit it is necessary to consider its variations in all pressure sensitive points. In such situation changing the pressure in the process means selecting a new pressure distribution.

Adjusting the pressure distribution for the sake of changing the plant performance based on the market condition, is the easiest way which can be applied with minimum needed cost.

Table 4 shows 5 pressure distribution in the process. As can be seen plant wide net profit and liquid recoveries change as the pressure distribution change.

CONCLUSIONS

Stream pressure drop plays an effective role in cryogenic liquid recovery plants. This is due to the effects of stream pressure on its temperature. In this paper the influence of the process stream pressure on the performance of these plants was analyzed.

The place and value of pressure drop in one hand, and the equipment that reduces the stream pressure in the other hand can change many parameters that are important in design of NGL recovery processes. The effects of the stream pressure on the performance of an NGL unit as a case study were analyzed. The results showed that the products specification and operating cost of the plant changes with the variations in the pressure distribution in the process. At last the plant wide net profit was selected as a final criterion for adjusting the pressure distribution.

There are many variables which can affect the products price. The market condition is the most determining factor and the plant wide net profit is a function of it. But in some cases the market is not the only noticeable element. Because of the strategic value of the products sometimes it is necessary to change the plant products without considering the market condition. Variation of the pressure distribution due to the new situation is a useful method for setting the plant performance to the desirable condition. Also adjusting the plant characteristics by this parameter can be used as a method with minimum retrofitting cost.

Nomencluture

AC-1	Air cooler
AC-2	Air cooler
AC-3	Air cooler
C-1	Compressor
C-2	Compressor
C-3	Compressor
C-4	Compressor
C-5	Compressor
W-1	Compressor Work
W-2	Compressor Work
W-3	Compressor Work
W-4	Compressor Work
W-5	Compressor Work
Wex-1	Expander Work
E-6	Heat exchanger
MSHEX 1	Multi stream heat exchanger
MSHEX 2	Multi stream heat exchanger
VLV-1	J-T valve
VLV-2	J-T valve
VLV-3	J-T valve
VLV-4	J-T valve
VLV-5	J-T valve
VLV-6	J-T valve
VLV-7	J-T valve
V-1	Flash drum
V-2	Flash drum

Abbreviation

NGL	Natural Gas Liquids

HHV Higher Heating Value
LNG Liquefied Natural Gas
Ethane recovery (Mass flow of ethane in the feed gas - mass flow of ethane in the residue gas)/mass flow of ethane in the feed gas

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