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RESEARCH ARTICLE

Heavy hydrocarbon recovery with integration of turboexpander and JT valve from highly CO_2-containing natural gas for gas transmission pipeline

Fauzi Yusupandi[1], Pramujo Widiatmoko[2], Ira Febrianty Sukmana[2], Hera Rahma Fitri[2], Mitra Eviani[2,3], Hary Devianto[2,*]

[1]Department of Chemical Engineering, Institut Teknologi Sumatera, Jl. Terusan Ryacudu, Way Huwi, Kec. Jati Agung, Lampung Selatan 35365, Indonesia
[2]Department of Chemical Engineering, Institut Teknologi Bandung, Jl. Ganesha No. 10, Bandung 40132, Indonesia
[3]Ministry of Energy and Mineral Resources Republic of Indonesia, Research and Development Agency for Energy and Mineral Resources, Research and Development Centre for Oil and Gas Technology, LEMIGAS, Ciledug, Jakarta Selatan, Indonesia

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OBJECTIVES Demand of natural gas is predicted to increase since many valuable products can be produced. Water and heavy hydrocarbon content are the key for gas pipeline facility. To meet requirement of natural gas transportation, dehydration unit (DHU) and hydrocarbon dew point control unit (DPCU) are necessary to avoid water and hydrocarbon condensation during transmission. The conventional dehydration technology, TEG contactor, can lower water content from 1,304 mg/m^3 to 80.35 mg/m^3 where the maximum limit of water content in natural gas is 97 mg/m^3 to prevent hydrate formation. METHODS DPCU is installed to remove heavy hydrocarbon, especially C_{5+}. Integration of JT valve and turboexpander was employed to obtain the low gas dew point. The hot gas stream that entered the JT valve was observed. RESULTS The lower hot bypass gas was applied, the lower hydrocarbon dew point and the more condensate flowrate was achieved. The highest power generation can be gained at low hot gas flow ratio which also influenced the exit pressure and temperature of compressor. CONCLUSIONS In pipeline simulation, the pressure and temperature drop occurred at the high hot gas rate. To examine the arrival condition, dew point curves were generated and showed that the limitation of hot gas flow ratio has to be below 0.6 to prevent heavy hydrocarbon condensation in pipeline.

KEYWORDS dew point; heavy hydrocarbon; JT valve; natural gas; turboexpander

1. INTRODUCTION

Natural gas is the raw materials that can be utilized in many sectors such as power generation; petrochemical industries mainly for ammonia and urea production; residential consumption and transportation (International Energy Agency (IEA) 2022). Treatment of natural gas consists of high-pressure separator (HP Separator) to separate C_{10+} hydrocarbon and produced water, amine treating to remove acid gas (H_2S and CO_2), dehydration unit for water removal and dew point control unit (DPCU) for C_{5+} separation (Uwitonze et al. 2020). These processes are required to meet the specification of sales gas that is transported by pipeline. Natural gas pipelines are designed to transfer single-phase gaseous fluid. The hydrocarbon condensation in the pipeline is avoided so that the DPCU play a vital role in sales gas characteristic. DPCU generates a liquid hydrocarbon, containing mainly C_{5+}, as natural gas liquid (NGL) product (Galatro and Marín-Cordero 2014; Rahimpour et al. 2011; Vatani et al. 2013).

There are many DPCU technologies which applied in industrial scale such as mechanical refrigeration using propane, Joule-Thomson (JT) valve (Shoaib et al. 2018), turboexpander, lean oil absorption (Díaz Rincón et al. 2016), solid bed adsorption, twister technology, and membrane separation (He and Ju 2014). Among the DPCU techniques, JT valve offers the low operating cost and simple operation. However, JT valve can only be operated at low gas rates and has a high pressure drop that requires sales gas compressor with external electricity from power plant (Mokhatab et al. 2015; Noaman and Ebrahiem 2021). On the other hand, turboexpander method can generate electricity from gas expansion process

*Correspondence: hardev@itb.ac.id

TABLE 1. Evaluation results of kinetic constants.

Stream	Raw Gas	Dehydrated gas	Sales Gas*
P (barg)	62.05	60	55.42
T (°C)	40.00	40.37	38.82
Flowrate (MMSCFD)	225.00	223.70	223.50
	Mole Fraction		
CO_2	0.136386	0.134733	0.134769
Nitrogen	0.006999	0.006986	0.006990
Methane	0.827717	0.831246	0.831683
Ethane	0.016298	0.016322	0.016321
Propane	0.003500	0.003495	0.003489
i-Butane	0.003000	0.003007	0.002993
n-Butane	0.000900	0.000902	0.000896
i-Pentane	0.000400	0.000401	0.000395
n-Pentane	0.001100	0.001102	0.001081
n-Hexane	0.000400	0.000401	0.000380
n-Heptane	0.000500	0.000502	0.000437
n-Octane	0.000400	0.000401	0.000290
n-Nonane	0.000200	0.000201	0.000105
n-Decane	0.000200	0.000201	0.000070
H_2O	0.002000	0.000100	0.000100
Total	1.000.000	1.000.000	1.000.000

*Hot gas flow ratio in DPCU was 0.2.

and achieve low hydrocarbon dew point but the dehydration unit was compulsory to prevent hydrate formation (Capata and Pantano 2020; Chekardovskiy et al. 2016; Mutiara et al. 2016). Combination between JT valve and turboexpander to obtain desired gas dew point is an attractive approach.

In this study, the DPCU was performed with a high flowrate and high CO_2-containing natural gas. The JT valve and turboexpander was applied to prevent liquid hydrocarbon formation during pipeline transportation. The hot gas flow ratio that flowed to JT valve was varied to investigate the gas dew point, power production, condensate flowrates, arrival temperature and pressure. The dew point curves were generated to evaluate the arrival condition. This work depicted that the integration between JT valve and turboexpander can be an alternative technology to achieve low gas dew point and to minimize electricity requirement in compressor.

2. RESEARCH METHODOLOGY

The natural gas was from well head in an eastern district of Indonesia. The composition of natural gas with flowrate of 225 MMSCFD was shown in Table 1. The natural gas had no sulfur impurities such as H_2S and mercaptan while the content of CO_2 was extremely high (up to 13.6 mol%). The operating temperature and pressure from well head were 40°C and 62.05 barg, respectively.

A steady-state simulation was carried out by ASPEN HYSYS V.10 software and the SRK-TWU fluid package was used to calculate thermodynamic properties in dehydration process and heavy hydrocarbon liquefaction in dew point control unit (DPCU) (Díaz Rincón et al. 2016). A high-pressure natural gas from well was firstly treated in high pressure separator (HP Separator) to separate produced water. TEG contactor was installed to reduce water content in natural gas (Hidayat et al. 2020). Maximum limitation of water content was 97 mg/m^3 to avoid hydrate formation in DPCU that

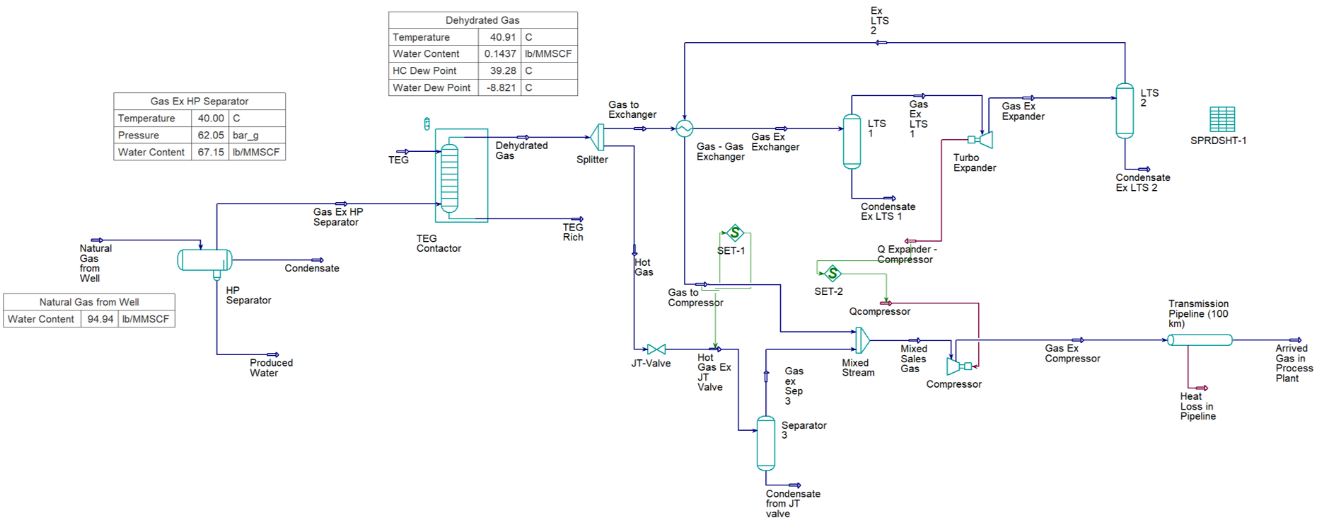

FIGURE 1. Process Flow Diagram (PFD) of dehydration and dew point control unit.

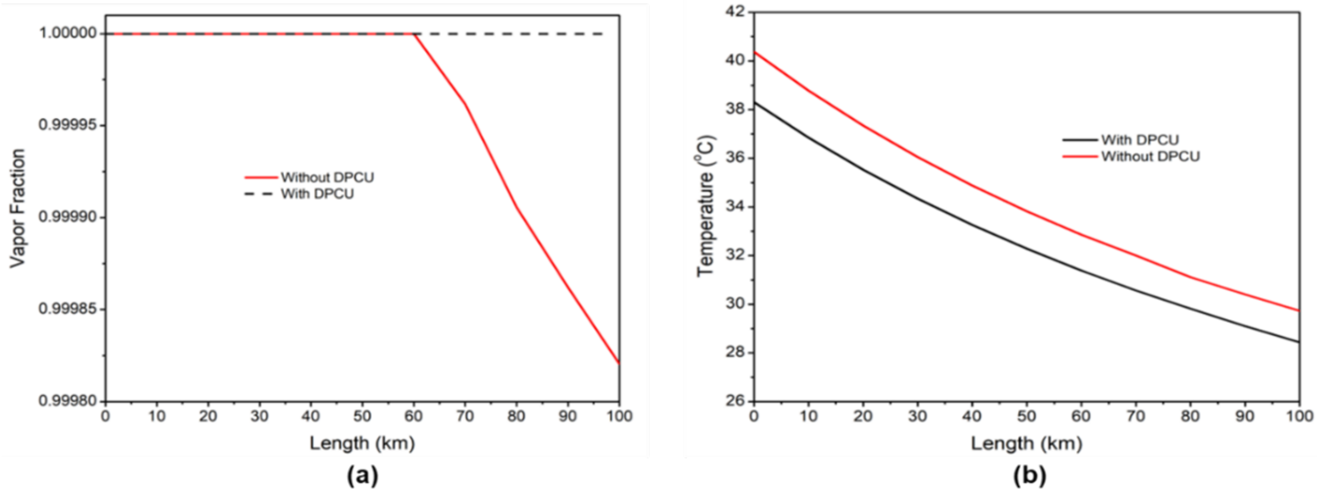

FIGURE 2. (a) Vapor fraction (b) temperature profiles without and with DPCU along pipeline.

operated in extremely low temperature (Díaz Rincón et al. 2016). The stream after dehydration column was split to two units of DPCU, turboexpander-recompression and JT valve, to prevent hydrocarbon condensation in pipeline. The turboexpander downstream pressure was set to 35 barg and the exit pressure of JT valve was adjusted to an equal pressure of gas-gas exchanger downstream pressure. Natural gas after DPCU was transported through pipeline along 100 km to process plant to achieve arrival pressure higher than 10 barg. The effect of hot gas flow ratio at JT valve to gas dew point, power production, condensate flowrate, arrival pressure and temperature was observed. The process flow diagram in this

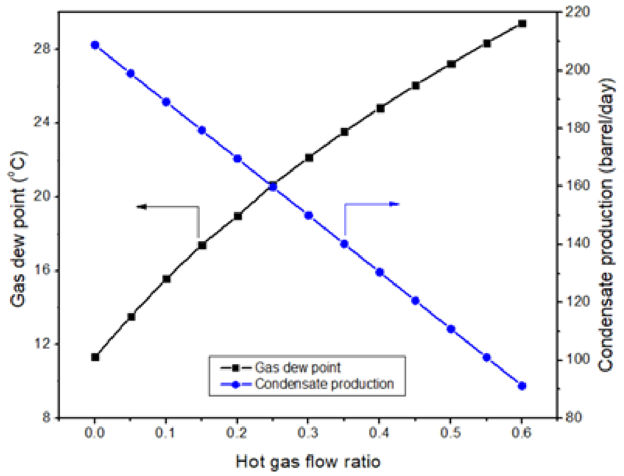

FIGURE 3. Gas dew point and condensate production at different hot gas flow ratio.

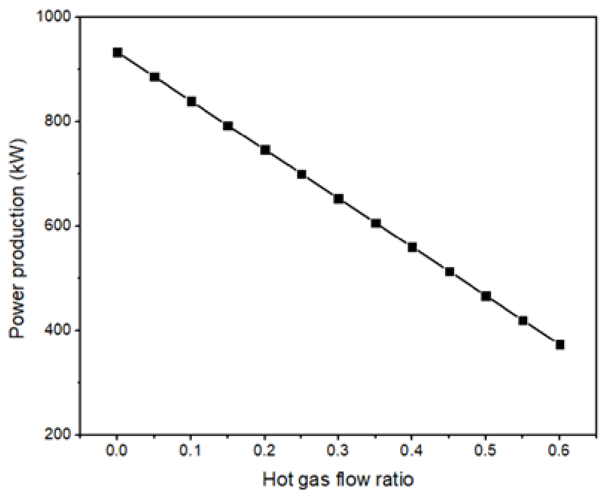

FIGURE 4. Effect of hot gas flow ratio on power production.

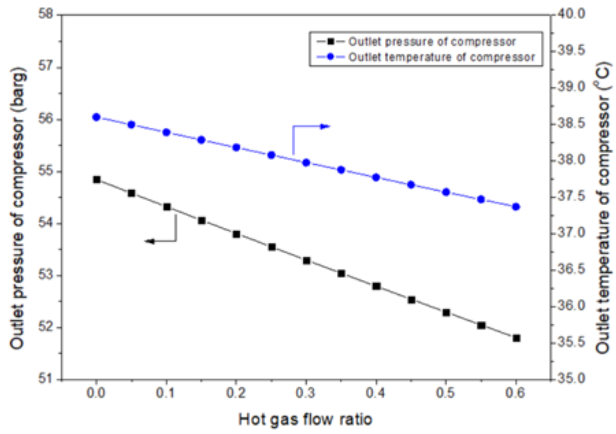

FIGURE 5. Influence of hot gas flow ratio on outlet pressure of compressor.

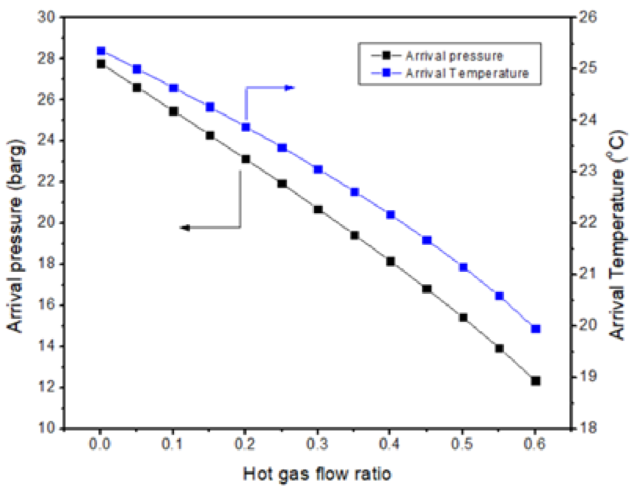

FIGURE 6. Arrival pressure and temperature in process plant at different hot gas flow ratio.

study was revealed in Figure 1.

3. RESULTS AND DISCUSSION

Water content in natural gas reduced from 1,607 mg/m^3 to 1,304 mg/m^3 in HP separator. TEG contactor with TEG solution can highly decreased water content to 80.35 mg/m^3. Afterward, dehydrated gas was cooled from 40 °C to 24 °C in Gas-Gas exchanger. The comparison of delivered natural gas without and with DPCU was shown in Figure 2. There is a condensation process of hydrocarbon without DPCU at 70 – 100 km. The presence of liquid hydrocarbon occurred when the hydrocarbon dew point in natural gas stream without DPCU was above the operating temperature in pipeline, dropped pressure and heavier compounds in feed gas. The gas dew point of natural gas without DPCU 30.1 °C while the operating temperature from 70 until 100 km was from 29.7 °C to 32 °C shown in Figure 3. When natural gas was treated in DPCU, the dew point value dropped to 10.85 °C as heavy hydrocarbon, dominated by C_{5+}, was removed.

Figure 3 showed that increasing the hot gas flow ratio can rose gas dew point. At high flowrate of hot bypass gas, the heavy hydrocarbons that was condensed from turboexpander was low. The JT valve in hot gas stream was installed to fit with the outlet pressure of turboexpander. However, the temperature drop in JT valve was insignificant to liquify heavier components in the hot gas stream so that the liquid heavy hydrocarbons was only produced from turboexpander. The trend of gas dew point was identical with condensate flowrate from LTS 1 and 2. The highest condensate production occurred when there was no hot bypass stream.

Moreover, the hot gas flow ratio affected electricity generation from turboexpander as shown in Figure 4. The graph indicates that power production increased with lower hot gas flow ratio. When hot gas flowrate was low, the high flowrate of gas flowed to turboexpander. The more mass flowrate entered the turboexpander, the higher the electricity was produced (Li et al. 2017). The highest power generation was approximately 933 kW when no hot gas flowed to JT valve. The power from turboexpander was utilized for required compressor energy. Figure 5 reveals that the exit pressure of compressor was influenced to hot bypass gas stream. In previous section, when there was no hot bypass gas, the highest power production was achieved so that the highest compressor downstream pressure was obtained. The higher hot gas flow ratio led to the outlet pressure of compressor was low since the electricity generation was also poor. Additionally, the value of outlet temperature of compressor had typical trend with exit pressure of compressor.

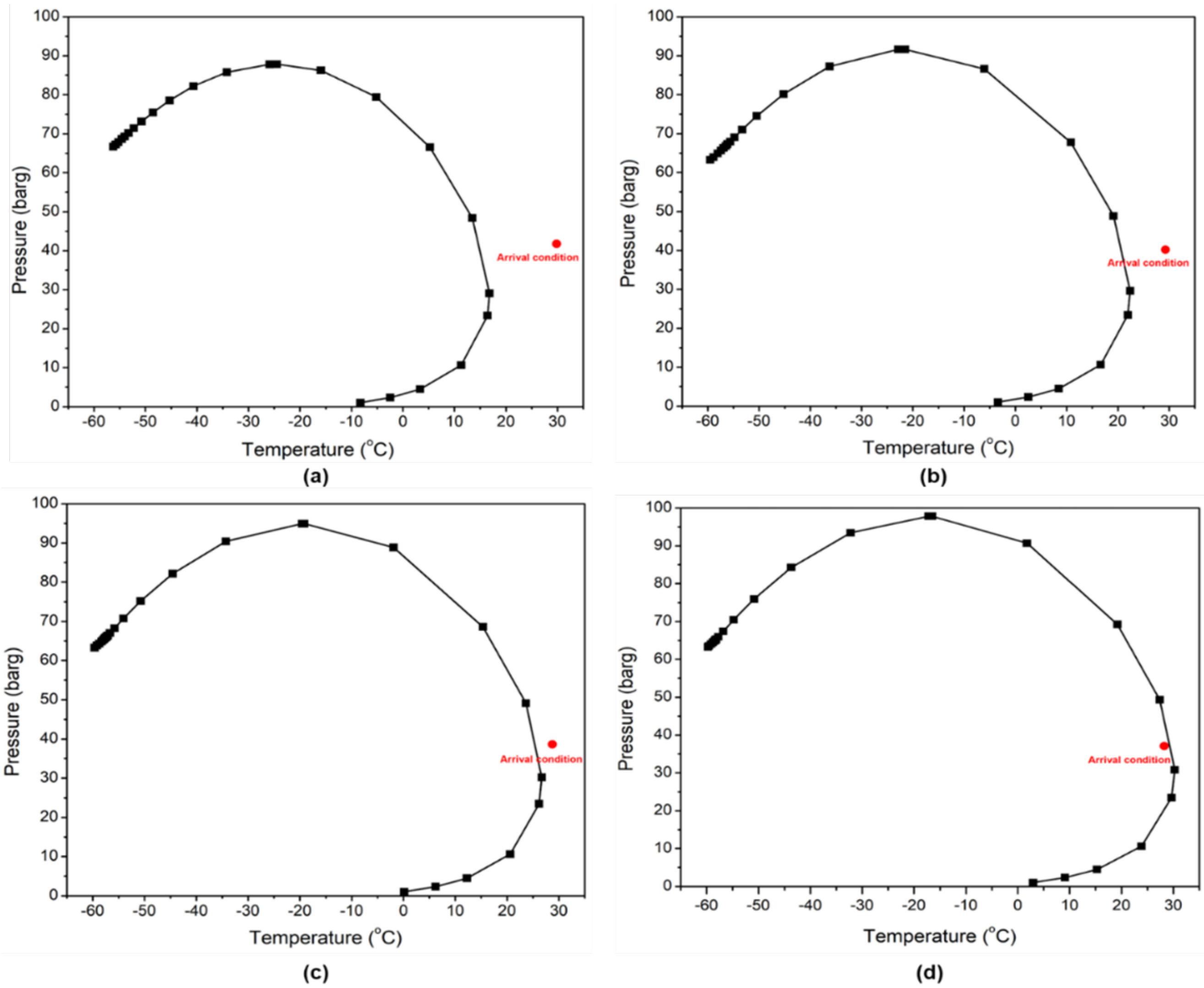

FIGURE 7. Arrival point in dew point curves at hot gas flow ratio (a) 0; (b) 0.2; (c) 0.4; and (d) 0.6.

This phenomenon directly influenced the arrival pressure and temperature in process plant as shown in Figure 6. With higher hot gas flow ratio, the low values of arrival pressure and temperature were gained. The high pressure drop at highest hot bypass stream was attributed to high gas flowrate that was transported through pipeline. To observe the condition in pipeline during transmission, the dew point curves was generated (Jalali et al. 2020) in Figure 7. At no hot bypass stream, the arrival point was far from the graph. Nevertheless, when the hot gas flow ratio elevated, the arrival condition was gradually close to dew point lines. At hot gas flow ratio of 0.6, the arrival gas was inside the dew point curves that caused the condensation process occurred due to heavier hydrocarbon was not recovered. Furthermore, the hot gas ratio of 0.4 was a maximum limit to bypass the hot gas flowrate and to prevent formation of liquid hydrocarbon during transmission.

4. CONCLUSIONS

Combination of turboexpander and JT valve was an alternative method to recover heavy hydrocarbon in natural gas processing. Based on simulation result, a hot gas flow ratio was a key that influence the performance of this technique. The higher gas dew point was led to the high hot bypass stream that also affected the lower condensate production. In addition, the power generation decreased when high flowrate of hot bypass gas flowed to JT valve. This condition was impactful to outlet pressure and temperature of compressor that use energy from turboexpander. Afterwards, the arrival pressure and temperature were influenced. Dew point curves confirmed the hydrocarbon condensation occurred at hot gas flow ratio of 0.6. This shows the integration of two DPCU technologies was possibly operated simultaneously with hot gas flow ratio below 0.6 to prevent condensation process during transmission.

REFERENCES

Capata R, Pantano F. 2020. Expander design procedures and selection criterion for small rated organic rankine cycle systems. Energy Science and Engineering. 8(10):3380–3414. doi:10.1002/ese3.710.

Chekardovskiy M, Chekardovskiy S, Ilyukhin K, Gladenko A. 2016. Upgraded Algorithm for Calculating the Turbo-Expander of Gas Distribution Stations. MATEC Web of Conferences. 73:6–11. doi:10.1051/matecconf/20167301020.

Díaz Rincón M, Jiménez-Junca C, Roa Duarte C. 2016. A novel absorption process for small-scale natural gas dew point control and dehydration. Journal of Natural Gas Science and Engineering. 29:264–274. doi:10.1016/j.jngse.2016.01.016.

Galatro D, Marín-Cordero F. 2014. Considerations for the dew point calculation in rich natural gas. Journal of Natural Gas Science and Engineering. 18:112–119. doi:10.1016/j.jngse.2014.02.002.

He TB, Ju YL. 2014. A novel process for small-scale pipeline natural gas liquefaction. Applied Energy. 115:17–24. doi:10.1016/j.apenergy.2013.11.016.

Hidayat M, Hartanto DT, Azis MM, Sutijan S. 2020. Studi Penambahan Etilena Glikol dalam Menghambat Pembentukan Metana Hidrat pada Proses Pemurnian Gas Alam. Jurnal Rekayasa Proses. 14(2):198. doi:10.22146/jrekpros.59871.

International Energy Agency (IEA). 2022. Gas Market Report, Q1-2022. International Energy Agency:61. https://www.iea.org/reports/gas-market-report-q1-2022.

Jalali A, Lotfi M, Zilabi S, Mohammadi AH. 2020. Recovery enhancement of liquid hydrocarbons in dew point control unit of natural gas processing plant. Separation Science and Technology (Philadelphia). 55(7):1407–1414. doi:10.1080/01496395.2019.1591450.

Li Y, Xu F, Gong C. 2017. System optimization of turbo-expander process for natural gas liquid recovery. Chemical Engineering Research and Design. 124:159–169. doi:10.1016/j.cherd.2017.06.001.

Mokhatab S, Poe WA, Mak JY. 2015. Handbook of Natural Gas Transmission and Processing. Oxford: Gulf Professional Publishing. doi:https://doi.org/10.1016/C2013-0-15625-5.

Mutiara T, Budhijanto, Made Bendiyasa I, Prasetya I. 2016. A thermodynamic study of methane hydrates formation in glass beads. ASEAN Journal of Chemical Engineering. 16(1):15–22. doi:10.22146/ajche.49670.

Noaman A, Ebrahiem E. 2021. Comparison of Natural Gas Hydrocarbon Dewpointing Control Methods. Journal of Advanced Engineering Trends. 40(2):99–116. doi:10.21608/jaet.2020.31288.1020.

Rahimpour MR, Seifi M, Paymooni K, Shariati A, Raeissi S. 2011. Enhancement in NGL production and improvement in water dew point temperature by optimization of slug catchers' pressures in water dew point adjustment unit. Journal of Natural Gas Science and Engineering. 3(1):326–333. doi:10.1016/j.jngse.2011.01.001.

Shoaib AM, Bhran AA, Awad ME, El-Sayed NA, Fathy T. 2018. Optimum operating conditions for improving natural gas dew point and condensate throughput. Journal of Natural Gas Science and Engineering. 49(September 2017):324–330. doi:10.1016/j.jngse.2017.11.008.

Uwitonze H, Hwang KS, Lee I. 2020. Improving NGL recovery process with dividing-wall column for offshore applications. Chemical Engineering and Processing - Process Intensification. 147(November 2019):107747. doi:10.1016/j.cep.2019.107747.

Vatani A, Mehrpooya M, Pakravesh H. 2013. Modification of an industrial ethane recovery plant using mixed integer optimization and shuffled frog leaping algorithm. Arabian Journal for Science and Engineering. 38(2):439–455. doi:10.1007/s13369-012-0433-9.