Heavy hydrocarbon recovery with integration of turboexpander and JT valve from highly CO₂-containing natural gas for gas transmission pipeline

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Received 21 February 2023; revised 30 June 2023; accepted 04 July 2023

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/m³ to 80.35 mg/m³ where the maximum limit of water content in natural gas is 97 mg/m³ to prevent hydrate formation. METHODS DPCU is installed to remove heavy hydrocarbon, especially C₅⁺. 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 C₁₀⁺, hydrocarbon and produced water, amine treating to remove acid gas (H₂S and CO₂), dehydration unit for water removal and dew point control unit (DPCU) for C₅⁺ 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 C₅⁺, 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 Ebrahim 2021). On the other hand, turboexpander method can generate electricity from gas expansion process.

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TABLE 1. Evaluation results of kinetic constants.

<table>
<thead>
<tr>
<th>Stream</th>
<th>Raw Gas</th>
<th>Dehydrated gas</th>
<th>Sales Gas*</th>
</tr>
</thead>
<tbody>
<tr>
<td>P (barg)</td>
<td>62.05</td>
<td>60</td>
<td>55.42</td>
</tr>
<tr>
<td>T (°C)</td>
<td>40.00</td>
<td>40.37</td>
<td>38.82</td>
</tr>
<tr>
<td>Flowrate (MMSCFD)</td>
<td>225.00</td>
<td>223.70</td>
<td>223.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mole Fraction</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>0.136386</td>
<td>0.134733</td>
<td>0.134769</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0.006999</td>
<td>0.006986</td>
<td>0.006990</td>
</tr>
<tr>
<td>Methane</td>
<td>0.827717</td>
<td>0.831246</td>
<td>0.831683</td>
</tr>
<tr>
<td>Ethane</td>
<td>0.016298</td>
<td>0.016312</td>
<td>0.016321</td>
</tr>
<tr>
<td>Propane</td>
<td>0.003500</td>
<td>0.003495</td>
<td>0.003489</td>
</tr>
<tr>
<td>n-Butane</td>
<td>0.003000</td>
<td>0.003000</td>
<td>0.002993</td>
</tr>
<tr>
<td>n-Pentane</td>
<td>0.003100</td>
<td>0.003102</td>
<td>0.001081</td>
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<tr>
<td>n-Hexane</td>
<td>0.000400</td>
<td>0.000401</td>
<td>0.000380</td>
</tr>
<tr>
<td>n-Heptane</td>
<td>0.000500</td>
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<td>0.000437</td>
</tr>
<tr>
<td>n-Octane</td>
<td>0.000400</td>
<td>0.000401</td>
<td>0.000290</td>
</tr>
<tr>
<td>n-Nonane</td>
<td>0.000200</td>
<td>0.000201</td>
<td>0.000105</td>
</tr>
<tr>
<td>n-Decane</td>
<td>0.000200</td>
<td>0.000201</td>
<td>0.000070</td>
</tr>
<tr>
<td>H₂O</td>
<td>0.002000</td>
<td>0.000100</td>
<td>0.000100</td>
</tr>
<tr>
<td>Total</td>
<td>1.000.000</td>
<td>1.000.000</td>
<td>1.000.000</td>
</tr>
</tbody>
</table>

*Hot gas flow ratio in DPCU was 0.2.

and achieve low hydrocarbon dew point but the dehydra-
tion 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 CO₂-containing natural gas. The JT valve and turboexpander was applied to prevent liquid hydrocar-
bon 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, ar-
river temperature and pressure. The dew point curves were generated to evaluate the arrival condition. This work de-
picted that the integration between JT valve and turboex-
pander 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 H₂S and mercaptan while the con-
tent of CO₂ was extremely high (up to 13.6 mol%). The operat-
ing 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 con-
tent was 97 mg/m³ to avoid hydrate formation in DPCU that
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
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 301 °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 liquefy 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](image-url)
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


