Analysis of the condensate phase in offshore pipe gas company

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Abstract. Gas transportation is usually done using pipes. As was done in one of the Gas Companies. In gas transportation consists of suppliers (Station A) and receivers (station C). From the supplier to the receiver goes through a very far pipe. Gas that passes through the pipeline has a composition consisting mostly of methane, but it is undeniable that there is still heavy carbon and impurities in the gas. Heavy carbon and various impurities contained in the gas will disrupt gas transportation in the pipeline because it can cause condensate. Condensate consists of heavy carbon and impurities which changes phase into liquid. The occurrence of liquid is caused by external and also internal influences, especially on the temperature and pressure that is treated to the gas. Condensate in the pipe will cause obstruction or decrease the volume in the pipe and otherwise it will cause internal corrosion. In the Gas Company there is an offshore pipeline that has the deepest depth of 70 meters. This elevation allows condensate inundation to occur in the offshore pipeline. The purpose of this study was to determine the effect of operating conditions on the occurrence of the existing condensate phase in the offshore pipeline between B Station B and C Station, which is 105 km away. The method used is the collection of gas composition data through gas chromatography analysis at station A, piping specifications, operating conditions at station B, and Hysys Aspen Simulation. It can be concluded that the offshore pipeline between B station and C station formed condensate (liquid phase) on 2nd day. The operating pattern of the envelope phase shows that in this condition natural gas condensate is formed because it is in the gas-liquid phase. If the methane composition and sea temperature are getting smaller, the possibility of natural gas condensate formation will be even greater.

1. Introduction
In the process of natural gas transmission, onshore and offshore pipes are often used, in addition to still using tankers or tank cars. Offshore or offshore pipelines are used as a means of transmitting natural gas through the sea. One example of an offshore pipeline that is used is the gas transmission pipeline network between Station B - station C. This pipeline network is parallel to the Station A – D Station pipeline network [1]. This pipeline network is known as the South Sumatra - West Java (South Sumatra West Java - SSWJ) transmission line with the aim of increasing the supply of natural gas for industries in Java. In addition, the construction of an offshore pipeline is used to connect gas from the supply point to gas customers or consumers and land receiving facilities [2]. The use of offshore pipelines is a more effective way of transmitting gaseous fluids at the point of supply in terms of capacity and distance traveled. Several technical obstacles often occur in the process of natural gas transmission using offshore pipelines. Sea temperature,
operational pressure and elevation in pipelines are technical constraints in the gas transmission process with offshore pipelines. Deep sea temperatures and pressures that tend to be lower often produce condensate in natural gas. The high temperature fluid flowing in the pipe will come into contact with the cross section pipe which has a low temperature and will convert some of the fluid into gas and liquid [3].

The pressure and temperature factors take into account the binding forces between the gas molecules. In addition, the gas fluid through some local bending will collide with a cross section that is formed like an elbow. This resulted in the formation of a liquid phase at several elevations in the offshore pipe [4].

On 4th day there is condensate at station C which exceeds the sumptank level. There is concern that this condition can affect the flow of gas in the offshore pipeline. The presence of condensate is also detrimental to the company due to the obstruction of gas distribution in the pipeline. Condensate in natural gas can damage piping installations because the content in this condensate is in the form of heavy carbon and gas impurities. Damage that can occur such as corrosion of natural gas distribution pipes. There are two offshore pipes owned by National Gas Company. The first one stretches between station B - station C and the second stretches between Station B - Station D. The offshore pipe has a pipe length of 105 km and a deepest of 70 meters. The offshore piping system does not have a tool to detect condensate. Based on the description above, the purpose of this study is to determine the effect of operating conditions on the occurrence of the existing condensate phase in the offshore pipeline network between B Station and C Station which is 105 km away.

1.1. Offshore pipe specifications and environmental conditions

1.1.1. Offshore pipe specifications. Inline Inspection: in the form

- internal diameter : 30.5 inches
- out diameter : 32 inch
- pipe length : 101 km
- wall thickness : 19.05 mm
- Roughness : 0.0005 inch
- nominal diameter : 32 inch
- ambiance temperature : 68 ° F
- pipe material : carbon steel
- std (standard pipe) : API 5L

Figure 1. Illustration of offshore pipe (A Station, B Station, and C Station).
1.1.2. Environmental conditions
- Sea temperature : 39.3 °C

1.2. Natural gas
Natural gas in Indonesia has a fairly dominant role after the role of oil as the main energy source has begun to be reduced. Moreover, with the commitment given by the government in the Clean Development Mechanism to the Kyoto Protocol, natural gas has begun to be chosen because of its lower pollution levels.

The Potential of Natural Gas in Indonesia apart from petroleum, Indonesia has quite large natural gas reserves, namely 170 TSCF and annual production of 2.87 TSCF, with this composition Indonesia has a reserve to production (R / P) of 59 years. Natural gas also has a stable price because it is far from political content, unlike petroleum. The products of natural gas used are LPG (Liquid Petroleum Gas), CNG (Compressed Natural Gas), LNG (Liquid Natural Gas) and Coal Bed Methane (CBM) which are non-conventional sources that are being developed in Indonesia (Kementerian ESDM, 2018-2027).

1.3. Composition of natural gas
Natural gas or natural gas also has a chemical composition like crude oil, only more simply, consisting of a mixture of compounds whose main elements consist of hydrogen atoms (H) and carbon atoms (C) or often referred to as hydrocarbon compounds, starting from C1 (methane) to C4 (Butane) sometimes there is also C5 + (pentane and heavier) which is already present in liquid form as condensate. From this it can be concluded that the composition of natural gas in terms of its carbon molecular compounds only consists of C1 to C4. So the constituent of natural gas only consists of CH4 (methane), C2H6 (ethane), C3H8 (propane), and C4H10 (butane) [5]. So compared to petroleum, in natural gas the number of carbon atoms is shorter. In general, natural gas is composed of the largest component of methane so that natural gas that has met the specifications for selling gas has properties close to methane properties.

Natural gas [6] can occur alone or exist together with crude oil. In addition, other compounds that are often present with it are carbonic acid gas (carbon dioxide or CO2), helium gas (He), mercaphthan (RSH) and water vapor (H2O) and metals / metals. The heavy metals present are Vanadium (V) and mercury or mercury (Hg). The content of other compounds in natural gas is undesirable, because these compounds are impurities or are often called impurities, which can disturb the next gas process [7].

1.4. Condensate
Natural gas condensate is a simple condensate that sometimes contains natural gasoline because it contains hydrocarbons which have the same boiling point as gasoline. Natural gas condensate usually consists of hydrocarbons ranging from C4 to C15 which mostly contain 25-95% by weight of organic compounds C6, C7 and C8. In natural gas the condensate consists of hexane, cyclohexane and benzene as C6 hydrocarbons; heptane and toluene as C7 hydrocarbons while octane, ethyl benzene, and xylene are considered C8 hydrocarbons [8]. Condensate is formed by condensation of steam or gas in the form of liquid hydrocarbons which will be separated from natural gas due to changes in temperature and pressure when it reaches the well for separation on the surface. The condensed liquid usually returns to the boiler upstream but if there is natural gas condensate present in the pipe it will be separated and collected through natural gas separation in the slug catcher, scrubber outlet and delivery scrubber to get natural gas free from condensate, liquids and particles. impurity.

This condensate contains hydrocarbon components of important and valuable raw material fuels. Natural gas or natural gas can occur alone or exist together with crude oil. In addition, other compounds that are often present with it are carbonic acid gas (carbon dioxide or CO2), helium gas (He), mercaphthan (RSH) and water vapor (H2O) and metals / metals. The heavy metals present are Vanadium (V) and mercury or mercury (Hg). The content of other compounds in natural gas is undesirable, because these compounds are impurities or are often called impurities, which can disturb the next gas process [7].
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1.5. Gas distribution system through piping

The distribution or distribution of gas through pipelines must have adequate infrastructure in the construction or design of the pipe. Piping infrastructure has begun to develop in Indonesia due to its effectiveness and efficiency in all sectors. The piping industry can be divided into two broad areas, namely transmission and distribution. Transmission pipelines are used to transport large amounts of natural gas over long distances and at high pressure (300-1400 psig). Distribution pipes are used to deliver gas from the point of supply to consumers at a lower pressure than transmission pipes and usually take supply from transmission pipes [1].

The transmission pipeline network is a pipe network that has a large diameter and high pressure, so it has a large gas distribution capacity. The pressure in this transmission pipeline can be anywhere from 200 psig to 1500 psig. This pressure is used to provide potential energy to the gas so that it can flow in the pipe. The transmission pipe consists of at least 3 main components, namely the transmission pipe itself, the compressor and the offtake station.

The distribution of gas through distribution pipes is the last stage before the gas enters the customer's installation. The distribution pipe gets gas from the transmission pipe through the delivery point which is called the city gate. At this city gate the gas from the transmission pipe is given an odorant (odor) a kind of mercaptant compound, as an anticipation that the gas can be smelled when a gas leak occurs in the distribution pipeline network. Then the pressure regulation process is also carried out, so that the pressure is in accordance with the pressure regime in the distribution pipe which is generally lower than the transmission pipe.

2. Research methodology

The methodology in this research is as follows:

2.1. Gas chromatography data collection at a station

The composition of natural gas at A station is recorded including methane, ethane, propane, i-butane, n-butane, i-pentane, n-pentane, n-hexane, n-heptane, n-octane, n-nonane, nitrogen, carbon dioxide, water, and sulfur.

2.2. Collecting data at B station

- The operating conditions at B station are recorded including pressure, temperature and flowrate.
- Recording is done every hour and every day so that you get the operating conditions before autopressure, during autopressure, and after autopressure.

2.3. Retrieval of offshore pipe specification data.

The data for the B Station - C Station offshore pipe specifications were taken in the form of internal diameter, out diameter, pipe length, wall thickness, roughness, nominal diameter, ambiance temperature, pipe material, std (pipe standard).

2.4. Observation at C station.

- The operating conditions at C station were observed including pressure and temperature.
- Observations were taken 3 different points each day which represented the conditions before autopressure, during autopressure, and after autopressure.
2.5. **Simulation using Hysys software.**

- Field data that has been taken on gas chromatography from A Station and operating conditions from B Station are processed as input data used in simulations with Hysys software.
- Three points of operating conditions (before auto pressure, during auto pressure, and after autopressure) that occur every day starting on 1\textsuperscript{st} day to 4\textsuperscript{th} day were used as experimental variables.
- The design for operation on the Hysys software is made according to field conditions, starting from the downstream of B Station to the upstream of C Station.
- The simulation is run at steady state.

2.6. **Making phase envelope curve using Microsoft Excel**

- Bubble points and dew points obtained through simulation results from Hysys software, graphed using Microsoft Excel. This graph from Microsoft Excel is called a phase envelope curve.
- Then the operating conditions at the three station points are combined in a phase envelope curve as material for analysis.

2.7. **Graphs formed from data input in excel are analyzed every day from 1\textsuperscript{st} day to 4\textsuperscript{th} day.**

3. **Results and discussion**

Based on the analysis of the data on operating conditions and gas composition on 1\textsuperscript{st} to 4\textsuperscript{th} day as well as data on the operating conditions performed by autopressure during the natural gas transmission process, it is seen that condensate is formed in the offshore pipeline between A station and C station. It can be seen from the phase envelope graph in Figure 4, that the operating condition line has entered the two-phase part of the curve. The phase envelope is a relationship between temperature and pressure which shows the conditions from the same side between the various phases of a chemical compound, a mixture of compounds, and a solution [10]. From the phase envelope curve, a line of operating conditions is inputted, the relationship between temperature and pressure on a daily basis, starting from the A Station input to the C Station output. Creating a phase envelope requires bubble point and dew point data[10]. Bubble point is a temperature that separates the liquid phase and partially the two phases (gas-liquid phase). While the dew point is a temperature that separates the gas phase and partially the two phases (liquid-gas phase) [10].
Table 1. Operating Conditions Of National Gas Company at B station for 1st to 4th day.

| Operating Condition       | units | B Station | Inlet Offshore Pipe | Outlet Offshore Pipe |
|---------------------------|-------|-----------|---------------------|----------------------|
| 1stDay                    |       |           |                     |                      |
| Before Autopressure       | T (°F)| 81,806    | 81,734              | 68,072               |
|                           | P (Psig) | 794,662  | 794,662            | 755,213             |
| AutoPressure              | T (°F) | 72,302    | 58,478              | 67,964               |
| (set Pressure :400 psig) | P (Psig) | 861,236  | 645,274            | 641,213             |
| After Autopressure        | T (°F) | 57,002    | 27,833              | 66,812               |
|                           | P (Psig) | 840,205  | 414,374            | 363,03               |
| 2ndDay                    |       |           |                     |                      |
| Before Autopressure       | T (°F) | 156,38    | 145,634             | 76,748               |
|                           | P (Psig) | 807,861  | 584,358            | 473,984             |
| AutoPressure              | T (°F) | 76,208    | 65,318              | 67,964               |
| (set Pressure :500 psig) | P (Psig) | 473,984  | 680,083            | 671,961             |
| After Autopressure        | T (°F) | 63,194    | 42,562              | 66,812               |
|                           | P (Psig) | 838,03   | 514,74             | 304                 |
| 3rdDay                    |       |           |                     |                      |
| Before Autopressure       | T (°F) | 73,292    | 63,158              | 67,334               |
|                           | P (Psig) | 823,526  | 664,854            | 585,373             |
| AutoPressure              | T (°F) | 77,108    | 68,72               | 67,982               |
| (set Pressure :500 psig) | P (Psig) | 834,114  | 699,663            | 695,602             |
| After Autopressure        | T (°F) | 63,104    | 41,163              | 67,928               |
|                           | P (Psig) | 843,831  | 508,648            | 481,816             |
| 4thDay                    |       |           |                     |                      |
|                           | T (°F) | 68,702    | 54,5                | 66,65                |
|                           | P (Psig) | 809,167  | 592,6253           | 505,4574            |

Table 2. Composition of Gas - Condensate at A Station.

| No | Day Components | Symbol | 1st | 2nd | 3rd | 4th |
|----|----------------|--------|-----|-----|-----|-----|
|    |                |        | Mole%|     |     |     |
| 1  | Methane        | C₁     | 84.10| 82.10| 83.76| 84.03|
| 2  | Ethane         | C₂     | 5.82 | 5.63 | 5.77 | 5.97 |
| 3  | Propane        | C₃     | 1.87 | 3.24 | 2.00 | 1.64 |
| 4  | i-Butane       | iC₄   | 0.33 | 0.60 | 0.38 | 0.31 |
| 5  | n-Butane       | nC₄   | 0.45 | 0.78 | 0.50 | 0.43 |
| 6  | i-Pentane      | iC₅   | 0.17 | 0.30 | 0.19 | 0.16 |
| 7  | n-Pentane      | nC₅   | 0.11 | 0.20 | 0.13 | 0.11 |
| 8  | n-Hexane       | nC₆   | 0.13 | 0.24 | 0.15 | 0.12 |
| 9  | n-Heptane      | nC₇   | 0.07 | 0.12 | 0.07 | 0.06 |
| 10 | n-Octane       | nC₈   | 0.02 | 0.04 | 0.02 | 0.02 |
| 11 | n-Nonane       | nC₉   | -    | 0.00 | 0.00 | 0.00 |
| 12 | Nitrogen       | N₂     | 1.34 | 1.27 | 1.33 | 1.33 |
| 13 | Carbon Dioxide | CO₂   | 5.57 | 5.49 | 5.69 | 5.80 |
| 14 | Water          | H₂O    | -    | 0    | 0    | 0    |
| 15 | Sulphur        | H₂S    | -    | 0    | 0    | 0    |
The autopressure condition is carried out to reduce the fluid pressure at B station outlet before transmission through the offshore pipe to the C station. This operating condition was carried out because C station had fulfilled customer needs and with the autopressure that occurred, several gas flows would be channeled directly to D station, which had a shortage of gas supply. With a change in the operating pattern that occurred for several days, on 4th Day there was an increase in the level of condensate formed at the Bojonegara offtake Station and closed the shut down valve. The parameters used to determine the formation of condensate in the offshore pipeline include natural gas composition, operating conditions during autopressure, operating conditions before and after autopressure. The outlet temperature of the offshore pipe will increase after autopressure occurs due to the increase in operating pressure.

3.1. Phase diagram
According to thermodynamic definition phase diagram (phase envelope) is a graph showing the pressure at which transition of different phases from a compound, respect to temperature [10,11]. Here an example of phase envelope of a compound and its region phases.

![Phase envelope diagram](image)

Figure 2. Phase envelope of natural gas on 1st day.

On 1st day, there is an autopressure mode in the natural gas transmission process. Figure 2 shows the characteristics of an offshore gas outlet pipe in the form of a phase envelope diagram. The operating temperature does not exceed the dew point formed and is still in the gas phase part of the envelope phase. This shows that at the operating temperature before autopressure, during autopressure, and after autopressure, two phases are not formed and no condensation occurs in the offshore pipe. The dew point formed was 56.27 °F with a pressure of 574.48 Psig. Dew point data is obtained from envelope utility in Hysys software. The operating conditions after autopressure on day 1 showed that the temperature and pressure were close to the dew point, namely at a temperature of 57 °F and a pressure of 840.21 Psig. This figure is obtained from the simulation results that have been running on the Hysys software in accordance with the specified operating conditions. If the pressure is lowered again, the operating conditions will reach their dew point. After passing through the offshore pipeline, natural gas will go through the PCV to reduce the pressure according to customer distribution needs.
On 2nd day there is an autopressure mode in the natural gas transmission process. Figure 3. shows the characteristics of an offshore gas outlet pipe in the form of a phase envelope diagram. The operating temperature does not exceed the dew point formed and is still in the gas phase part of the envelope phase. This shows that at the operating temperature before autopressure, during autopressure, and after autopressure two phases are formed and condensation occurs in the offshore pipe. The dew point curve formed was 82.79 °F with a pressure of 675.44 Psig. Dew point data is obtained from envelope utility in Hysys software.

Figure 3. Phase envelope of natural gas on 2nd day.

Figure 4. Phase envelope of natural gas on 3rd day.
On 3rd days there is an autopress mode in the natural gas transmission process. Figure 4 shows the characteristics of an offshore gas outlet pipe in the form of a phase envelope diagram. The operating temperature does not exceed the dew point formed and is still in the gas phase part of the envelope phase. This shows that at the operating temperature before autopressure, during autopressure, and after autopressure, two phases are not formed and condensation occurs in the offshore pipe. The dew point curve formed was 61.34 °F with a pressure of 592.07 Psig. Dew point data is obtained from envelope utility in Hysys software.

![Phase envelope of natural gas on 4th day.](image)

On 4th day there is an autopressure mode in the natural gas transmission process. Figure 5 shows the characteristics of an offshore gas outlet pipe in the form of a phase envelope diagram. The operating temperature does not exceed the dew point formed and is still in the gas phase part of the envelope phase. This shows that at the operating temperature before autopressure, during autopressure, and after autopressure, two phases are not formed and condensation occurs in the offshore pipe. The dew point curve formed was 53.55 °F with a pressure of 565.15 Psig. Dew point data is obtained from envelope utility in Hysys software.

The condensate formed in the offshore pipeline occurs due to internal and external factors. Internal factors are the composition of natural gas and operating conditions such as pressure, temperature and flowrate. If the composition of methane gas is getting smaller, then the possibility of forming natural gas condensate will increase. Meanwhile, external factors are sea elevation and temperature. With the deepest offshore pipe depth at 70 meters, the hydrocarbons in natural gas will experience a phase change. In this case, the factor that influences the formation of condensate is the composition of natural gas which is not good because the composition of methane is low so that the heavy carbon composition increases. The increasing heavy carbon composition shows that the dew point on the phase envelope graph is getting to the right.

Operating conditions such as temperature and pressure must be maintained so that condensate does not form in offshore pipes. The composition of natural gas must be treated to clean natural gas from impurities. Methods that can be done in cleaning natural gas from impurities and carbon by weight can be done by:
3.1.1. Doing pigging. Pigging aims to clean the pipes from dirt or condensate trapped in the pipes during the distribution process. Pigging can push impurities such as condensate and scale in the pipe. The edge is done by inserting the pig in the pig launcher which will be channeled using natural gas from the pipe to the pig receiver.

3.1.2. The presence of CO₂ removal. CO₂ is a gas impurities that must be removed because this content can cause corrosion in pipes. CO₂ removal can be done in 2 ways, namely using absorption and using a membrane.

3.1.3. Optimization of separator / scrubber performance. The separator / scrubber is used to separate the gas from the liquid contained in it by separating it based on density.

4. Conclusion
The offshore pipe between B station and C station formed condensate (liquid phase) on day 2. The operating pattern of the envelope phase shows that in this condition natural gas condensate is formed because it is in the gas-liquid phase. If the methane composition and sea temperature are getting smaller, the possibility of natural gas condensate formation will be even greater. The composition of natural gas must be treated, such as cleaning through a separator or by CO₂ removal. Another method that can be done is pigging the offshore pipe. Pigging aims to clean the pipes from dirt or condensate trapped in the pipes during the distribution process.

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References
[1] Ardiansyah 2008 Perancangan Sistem Perpipaan Transmisi Gas dari Muara Bekasi ke Muara Tawar Melalui Jalur Lepas Pantai. (Universitas Indonesia. Jakarta.)
[2] Ansory S and Fathaddin M T 2016 Optimasi Trmasportasi Gas Alam dari Lepas Pantai ke Fasilitas Penerima Darat Semin. Nas. Cendekiawan. Univ. Trisakti.
[3] Rachmat B, Purwanto C and Raharjo P 2011 Kajian Identifikasi Infrastruktur Jaringan Pipa Migas Bawah Laut Di Perairan Sebelah Utara Provinsi Banten J. Tek. Geol. Kelaut. 9(2) 79–96
[4] Supahar 2005 Kajian Numerik Sifat Densitas Sistem Hidrokarbon Gas Kondensat Berbasis Komposisi Menggunakan Persamaan Soave Redlich-Kwong”. Pros. Semin. Nas. Penelitian, Pendidik. Penerapan MIPA. Univ. Negeri Yogyakarta. 1–11
[5] Sujan S M A, Jamal M S, Hossain M, Khanam M and Ismail M 2015 Analysis of gas condensate and its different fractions of Bibiyana gas field to produce valuable products 50 59–64
[6] Medeiros L De, Arinelli L D O, Teixeira A M, Araújo D Q F, Química E De and Janeiro R De 2019 Supersonic separator for cleaner offshore processing of natural gas with high carbon dioxide content : Environmental and economic assessments 233 510–21
[7] Chotler Desemsi P 2011 Modifikasi Proses Pemisahan CO2 Kadar Tinggi dari Gas Alam (Universitas Indonesia)
[8] Goverment of Canada 2016 Risk Management Approach for Natural Gas Condensates Enviroment, Clim. Chang. Heal. Canada
[9] Kemendikbud 2015 Gas Proccesing. Jakarta
[10] Soetikno D, Kusdiantara R, Puspita D, Sidarto K A, Siagian U W R, Soewono E and Gunawan A Y Critical Point Analysis of Phase Envelope Diagram 5 1–4
[11] Davarikhah Q 2020 Prediction of a wellhead separator efficiency and risk assessment in a gas condensate reservoir