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Flowline Modification of Vapour Closed Drain to Acid Flare at Matindok CPP in Reducing CO2 Emission

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Abstract

Pertamina EP Donggi Matindok Field produces gas and condensate by transforming natural raw gas to sweet gas through several processes. LP Vent Stack is a facility to release non-hazardous gas such as N2 and O2 excess to ambient air. However, waste gaseous in Matindok Central Processing Plant (CPP) that comes from Condensate Tank, Closed Drain, and Produced Water Tank causing vapour release, where this vapour release is mainly detected from Closed Drain. Gaseous release from Closed Drain which contains high hydrocarbon and H2S with characterization of high Lower Explosive Limit (LEL) can cause potential explosive when contacted with heat source, electricity, or lightning. On January 20th 2022 and February 15th 2022, flame occurred in LP Vent Stack located in Matindok CPP. Flowline modification of Closed Drain to Acid Flare is conducted to prevent potential flame and reduce emission in LP Vent Stack. The gaseous release from Closed Drain is being modified to Acid Flare as purge, hence reducing the usual purge needed from fuel gas and able to reduce 352.86 kg of CO2 emission in 2022.

Keywords: Emission Reduction, CO2, Vapour Gas, Purge Flare

1. Introduction

Pertamina EP Donggi Matindok Field consists of two Central Processing Plant (CPP), namely Donggi CPP and Matindok CPP to produce gas and condensate. Donggi Matindok Field is a plant that processes natural gas raw materials into sweet gas through a series of processes to remove gas impurities such as CO_2, H_2S, and H_2O. Donggi Matindok Field has Acid Gas Removal Unit (AGRU), Dehydration Unit (DHU) and Dew Point Control Unit (DPCU) as the main process units. Apart from that, Donggi Matindok Field has an LP Vent Stack facility which functions to release/vent non-hazardous gaseous such as excess N_2 & O_2 from the main process into the ambient air. At AGRU, feed gas flow into KO Drum and Acid Gas Absorber. While in Acid Gas Absorber, feed gas will be contacted with MDEA solvent and rich solvent will be formed. Rich solvent will flow into Acid Gas Flash Drum and went to Amine Stripper Column and Amine Sump Drum. On the other hand, sweet gas formed in Acid Gas Absorber will flow into Sweet Gas KO Drum and went to DHU.

The large amount of waste gaseous produced in LP Vent Stack comes from the Condensate Tank, Closed Drain and Produced Water Tank causing vapour release, where the vapour release mainly comes from the Closed Drain. Closed Drain is a vessel to accommodate excess condensate/water from the Separator Unit and also to accommodate water/condensate from the main process. Closed Drain works at atmospheric pressure which is placed in the open underground. In Closed Drain conditions, a lot of liquid is produced with a fairly high content of dissolved hydrocarbon gas & H_2S, so the potential for vapour release in the Closed Drain is very high because there is a fairly high of pressure difference where the vapour still contains a lot of hydrocarbon gas & H_2S and gaseous hydrocarbons have a fairly high LEL.

According to Hospital (2018), the term LEL, or lower explosive limit, refers to the lowest concentration of a gas in air, in this example, a combination of evaporated hydrocarbons, that when combined with an ignition source, heat, electricity, or lightning, can cause a flash fire. The "explosive limits" on ambient temperature, "explosive limits" on ambient pressure, and "explosive limits" on fuel concentration are the three common categories of explosive limits (Wang, 2018). The temperature's explosive limits will expand with increasing ambient pressure; but, if the temperature is too low, even higher ambient pressure will escape, leaving the mixture insensitive to ignite. There is a range of two limits that correspond to the explosive limit of the fuel concentration: the upper explosive limit (UEL, the maximum fuel concentration) and the lower explosive limit (LEL, the least fuel concentration in air capable of explosion) (Keller, et. al., 2014).

If the lower explosion limit has been exceeded and the extent of this emission is not too low, an emission in a hazardous amount is present (Zinke, et. al., 2020). The oil and gas sector has seen a number of mishaps that have resulted in several fatalities, asset loss, and/or significant environmental damage (Ismail et. al., 2014). Statistics indicates that fire and explosion responsible for 85% of the accidents occurred in oil and gas industry (Chang and Lin, 2005). The venting explosion process of premixed fuel vapour and air in a half-open vessel have been studied by Wang, et. al. (2020) to analyze the overpressure dynamic process and flame evolution behaviour. Risks causing by fire and explosion also initiate a lot of studies to learn the flame characteristic and prevent flame in oil and gas industry, as follows.

Table 1. State of The Art

Authors	Year	Objective of Study
Mohamed G. Ali; Ahmed H. Besheer; M. H. M. Hassanean	2023	Study the accumulated of the exhaust gas emissions to serve as the source of the inert gas that flare systems use for purging.
Shimao Wang, Ye Zhao, Guoqing Li, Yongliang Xie, Dejian Wu	2022	Experiment using a 20-L small-scale vent tank, hydrocarbon-air fuel venting explosion tests were conducted to examine the effects of four distinct vent covers, each having an inherent rupture pressure of 10 kPa, on the overpressures and flame propagation characteristics.
C. Dücso, M. Ádám, P. Fürjes, M. Hirschfelder, S. Kulinyi, I. Bársony	2003	Experiment with mechanically stable, integrable calorimetric microsensors to acquire explosion-proof hydrocarbon monitoring.
Mohammed J. Ajrash AL-Zuraiji, Jafar Zanganeh, Behdad Moghtaderi	2019	Analyze how well an inline flame arrester works in a large-scale detonation tube to prevent methane explosions.
Y. F. Khalil	2017	Create a probabilistic model to estimate the workplace risks of explosions and fires caused by leaks that catch fire in confined places.
Guoqing Li, Jun Wu, Shimao Wang, Jie Bai, Dejian Wu, Sheng Qi	2021	Examine how the position of obstacles and the concentration of gasoline vapour affect gasoline-air fuel explosions, by considering factors variations in internal and external overpressure, flame propagation, and the link between flame and overpressure.
Javad Asadi, Esmaeil Yazdani, Yasaman Hosseinzadeh Dehaghani, Pejman Kazempoor	2021	Using Aspen HYSYS and MATLAB software to proposed flare gas recovery process based on liquid ring compressors, in which flare gases are compressed and treated simultaneously using methyl diethanolamine and simulated through custom models.

On January 20th 2022 and February 15th 2022, flame occurred in LP Vent Stack located in Matindok CPP followed by another flame on February 15th 2022. The fact that LP Vent Stack in Matindok CPP located near the Condensate Tank may evoke a bigger flame and even explosion, thus inflict worry among the workers. These events brought PT Pertamina EP Donggi Matindok Field to carry out initial problem that causing the flame using Fishbone issues and Failure Modes Effect Analysis (FMEA). The goals of this study are to prevent future potential flame, to maximize excessive HC gaseous from Closed Drain as purge in Acid Flare by conduct modification flowline using HYSYS simulation, and to calculate CO_2 emission reduction after the implementation of flowline modification.

2. Method

2.1 Fishbone Analysis (Ishikawa Diagram)

The use of the Ishikawa diagram was first proposed by Japanese professor Kaoru Ishikawa in the 1960's. Ishikawa diagram represent the connection between a result and the factors able to influence on the result. Luo et. al. (2017) considered Fishbone Diagram to make complex system organized, analyzing the causes of risk qualitatively. According to Botezatu et al. (2019), the primary steps in developing an Ishikawa diagram are defining the problem, developing the graphical representation, analyzing the information the diagram provides to identify the key factors or factors whose values could be altered, and creating an action plan based on the feedback from the previous stage. On the other hand, Romo et. al. (2013) highlighted the question of "why does this happen" in the making of Ishikawa Diagram.

2.2 Failure Modes Effect Analysis (FMEA)

Failure Modes Effect Analysis (FMEA) is a methodical approach to spotting and stopping process, product, and system issues before they emerge. This method focusing on preventing problems and enhancing safety. FMEA has been used in many industries such as aerospace, military, oil and gas, manufacture, and etc. The risk of failure is assessed using the risk priority number (RPN) value in the majority of modern FMEA methodologies (Sharma and Srivastava, 2018). The risk priorities of failure modes are determined through RPN, while RPN is obtained as multiplication of the severity (S), occurrence (O), and detection (D) of a failure. According to Stamatis (2003), a complete FMEA is consisted of four stages: (1) identify all known or possible failure modes; (2) verify the reasons and consequences of each failure; (3) rank the recognized failure modes according to their RPN; and (4) take corrective action for the more catastrophic failures.

2.3 HYSYS Simulation

Simulation is an essential step for modelling process before execution of the modification or improvement that is not yet exist or too expensive for experiment. HYSYS is one of the usual software used in oil and gas industry. Due to HYSYS's significantly faster solution replication, large and complicated models can be deployed in demanding scenarios like online real-time optimization. Given that HYSYS generates heat and material balance (HMB), most industries choose to utilize it as their oil process software (Olugbenga, 2021). Aspen HYSYS have been used to design a new gas plant. According to Sayed, et. al. (2017), the first step is to design methodology and cascade configuration of gas plant units based on feed gas composition, model the integrated development and optimization of gas treatment process, followed by conduct the model of the natural gas liquids extraction unit and fractionation train based on the required marketable products specifications. Furthermore, the economic analyzer software can be processed by Aspen HYSYS to determine the plant's anticipated capital expenditures.

2.4 Energy Efficiency and CO_2 Emission Reduction Calculations

Energy efficiency determined by total flow gas to Acid Flare in MMSCF units and converted to MMBTU multiplied by giga joule (GJ) units based on Calculation and Report of Greenhouse

Gases Inventory Guidelines (2018) from Ministry of Energy and Mineral Resources. The conversion can be seen in Equation below.

$DA_{BBG} = F_{BBG} \text{ x } K$
Where:
DA_{BBG} = Activity Data (TJ)
F_{BBG} = Natural gas consumption in a year (MMBTU)
K = Conversion factor (0.001055 TJ/MMBTU)

The energy efficiency generated from flow line modification of Closed Drain to Acid Flare is multiplied with CO_2 emission factor of natural gas from IPCC Guidelines for National Greenhouse Gas Inventories Volume 2 (Eggleston et. al., 2006) with value of 56.100 kg CO_2/TJ as stated in Greenhouse Gases Inventory in Energy Sector from Centre of Data and Information Technology, Energy and Mineral Resources, Ministry of Energy and Mineral Resources (2020).

3. Results and Discussion

3.1 Fishbone Analysis (Ishikawa Diagram)

After flame occurred on January 20th 2022 and February 15th 2022, Pertamina EP Donggi Matindok Field conduct a fishbone analysis to organize the cause behind the flame in LP Vent Stack at Matindok CPP using the main question "why a flame can be occurred in LP Vent Stack?". The identified causes are being classified as Man factor, Method factor, Material factor, and Facility factor. Material factors identified are the gaseous source is waste gas which dominated from unit 310 and the vapour gaseous composition dominated by hydrocarbon with high LEL. Methods factors identified are no current optimal methods to control venting gas and excessive hydrocarbon gaseous entering Closed Drain causing significant high pressure. Man factors identified are high level liquid causing high vapour release where Condensate Drain Standard Operating Procedure (SOP) from Separator is not applicable anymore. Facility factors identified are hydrocarbon gaseous vapour release flowline is flowed to LP Vent Stack and quantity of vapour release volume entering LP Vent Stack is not controllable and not monitored. The fishbone analysis is presented in Figure 1.

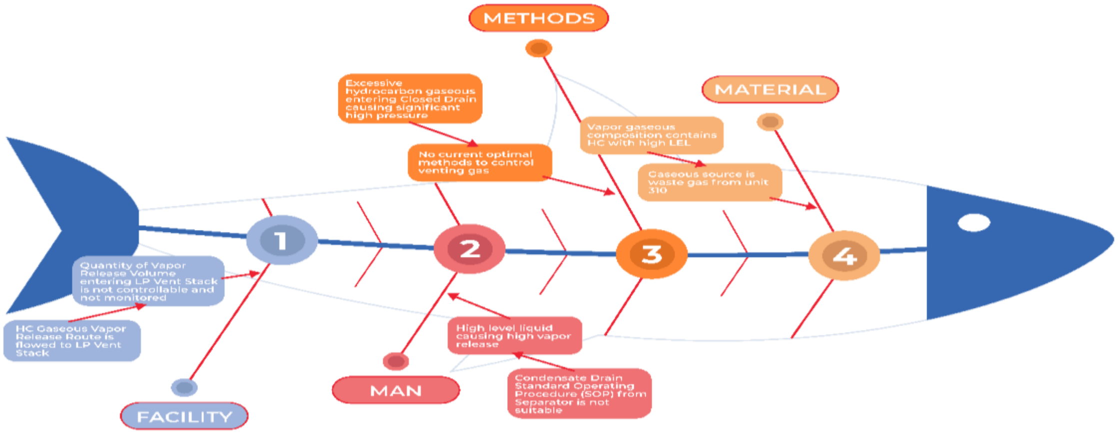


Figure 1. Fishbone Analysis of Flame in LP Vent Stack

3.2 Failure Modes Effect Analysis (FMEA)

LP Vent Stack is a facility used for venting excess non hazardous gas to atmosphere such as N_2 and O_2. LP Vent Stack receive gases from three Condensate Tanks, Produced Water Tank, and from Closed Drain Drum. Piping and instrumentation diagram of LP Vent Stack source can be seen in Figure 2.

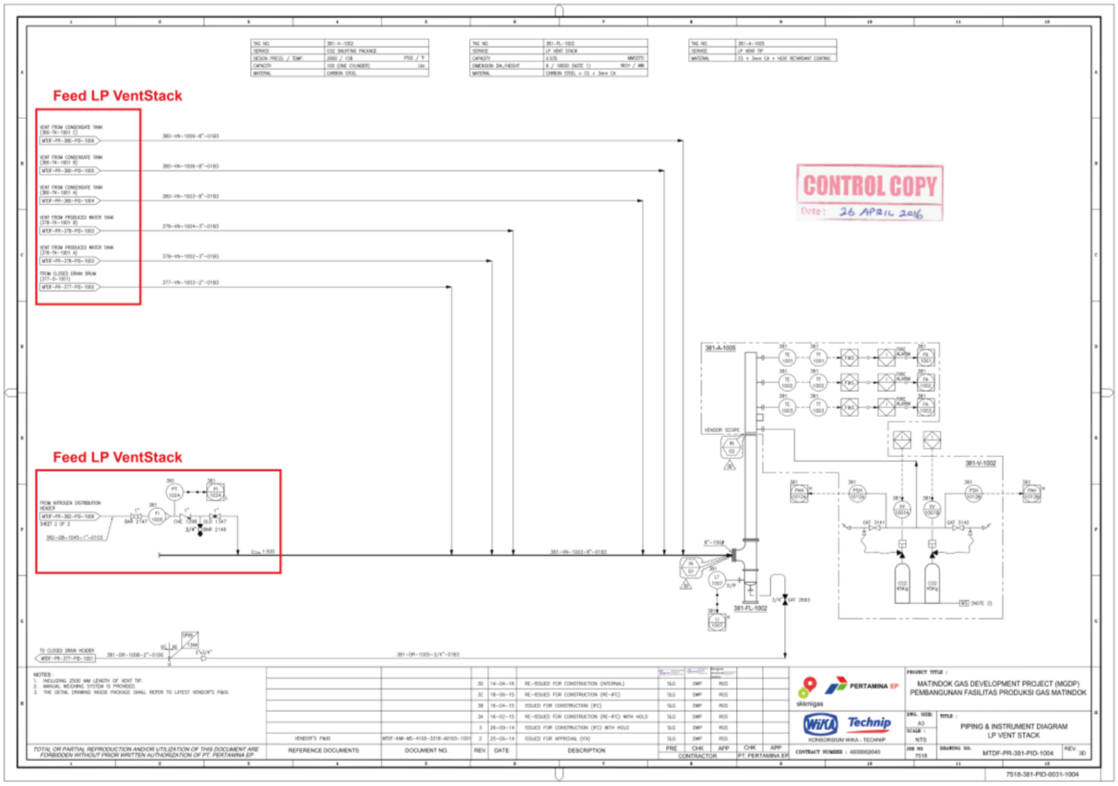


Figure 2. Feed of LP Vent Stack (Pertamina EP Donggi Matindok Field, 2016)

Closed Drain feed sources are from Sales Gas Metering, Feed Gas KO Drum, Liquid Gas Coalescer, Booster Compressor, After Cooler KO Drum, Liquid Gas Coalescer, Test Separator, HP Scrubber, HP Separator, HP Produced Water Filters, Wash Tower, and other units as seen in Figure 3. These contain a lot of liquid with a fairly high content of dissolved hydrocarbon gas & H_2S, causing the potential for vapour release in closed drains very high because there is a fairly high pressure difference where the vapour still contains hydrocarbon gas & H_2S. Hydrocarbon gas has a fairly high LEL, to such an extent that if vented into the atmosphere through the LP Vent will initiate the potential to form a combustion reaction if there is a source of heat, electrical energy, or lightning that reacts with free oxygen in the air (Fire Triangle). The existing flowline of Closed Drain to LP Vent Stack can be seen in Figure 4. These documents become the evidence to define risk priority number when conducting FMEA.

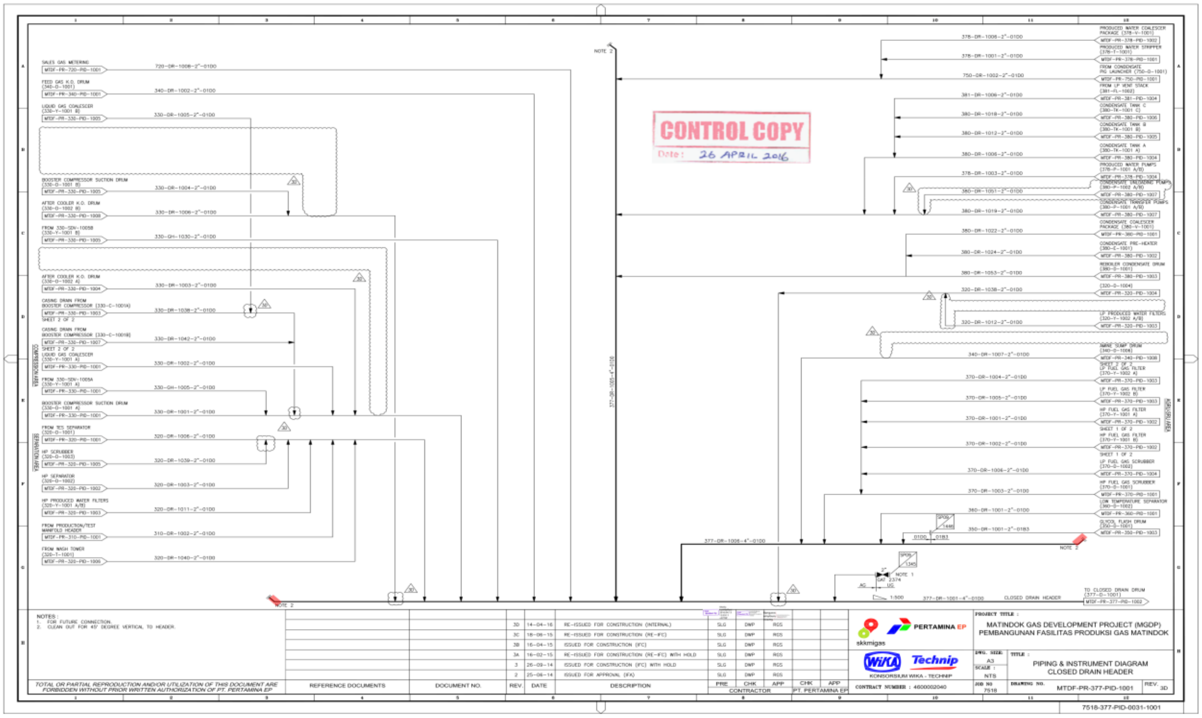


Figure 3. Feed Closed Drain (Pertamina EP Donggi Matindok Field, 2016)

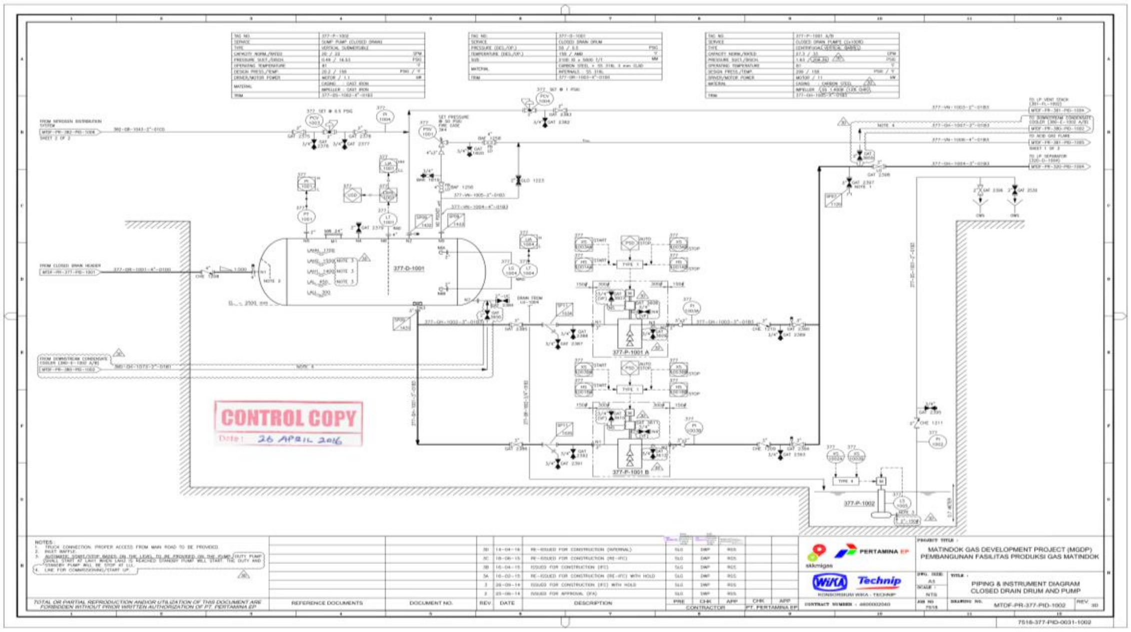


Figure 4. Current flowline of Closed Drain to LP Vent Stack (Pertamina EP Donggi Matindok Field, 2016)

FMEA Result as seen in Table 2 shows that the dominant cause is because the existing flowline of hydrocarbon gas vapour release facility from Closed Drain is going to LP Vent Stack. The actual condition also shows that quantity of vapour release volume enters LP Vent Stack is not controlled nor monitored, hence HC gas accumulation causing flame potential.

Table 2. FMEA Results

ID	Dominant Cause	Actual Condition	S	O	D	RPN	%Relative	%Cumulative
A	Existing flowline of hydrocarbon gas vapour release facility from Closed Drain is going to LP Vent Stack	Quantity of vapour release volume enters LP Vent Stack is not controlled nor monitored, hence HC gas accumulation causing flame potential	8	8	4	256	70	70
B	Source gas feed material in Closed Drain is waste gas process from unit 310, 320, 330, 340, 350, 360, and 380	High hydrocarbon gas composition with high LEL causing flame when contacted with heat ignition	4	4	4	64	18	88
C	Excessive hydrocarbon gas entering Closed Drain causing significant high pressure	No current method is optimal to control Closed Drain pressure	4	4	2	32	9	97
D	Standard Operating Procedure (SOP) Condensate Drain from Separator is not suitable	High level hydrocarbon causing high pressure, hence causing excessive vapour release	1	3	4	12	3	100

3.3 Alternative Solutions

After focusing on Fishbone Analysis and Failure Mode Effects Analysis, some alternative solutions are planned. First, flowline modification of Closed Drain vapour release from LP Vent

Stack to Acid Flare. Second, make a hydrocarbon gas processing facility from Closed Drain vapour release. Third, resize HP Separator to contain more condensate so it will not be flowed to Closed Drain. These solutions are assessed through the estimated cost, estimated duration, and operational aspect. The final assessment shows that flowline modification of Closed Drain vapour release from LP Vent Stack to Acid Flare is likely to be chosen with IDR 7,500,000 of estimated cost, 2 months of estimated duration, and easy installation.

Table 3. Alternative Solutions

Alternative Solutions	**Estimated Cost**	**Estimated Duration**	**Operational Aspect**
Flowline modification of Closed Drain Vapour Release from LP Vent Stack to Acid Flare	IDR 7,500,000	2 months	Easy Materials and Installation
Make a hydrocarbon gas processing facility from Closed Drain vapour release	IDR 2,000,000,000	1 year	Heavy Equipment, Complex Construction
Resize HP Separator to contain more condensate so it will not be flowed to Closed Drain	IDR 3,000,000,000	1 year	Heavy Equipment, Complex Construction

3.4 HYSYS Simulation Result

Before flowline modification of Closed Drain vapour release from LP Vent Stack to Acid Flare is performed, HYSYS simulation is needed to achieve estimated nozzle diameter from Closed Drain vapour release to Acid Flare. Nozzle diameter needed is based on the hydrocarbon composition from Closed Drain vapour released. To achieve hydrocarbon composition from Closed Drain vapour released, the HYSYS Simulation is first done by replicating the existing unit from Raw Gas to HP Separator resulting in raw condensate that goes to LP Separator and Feed Closed Drain. From Closed Drain there will be separation to Produce, to LP Separator, and vapour. The HYSYS Simulation scheme can be seen in Figure 5.

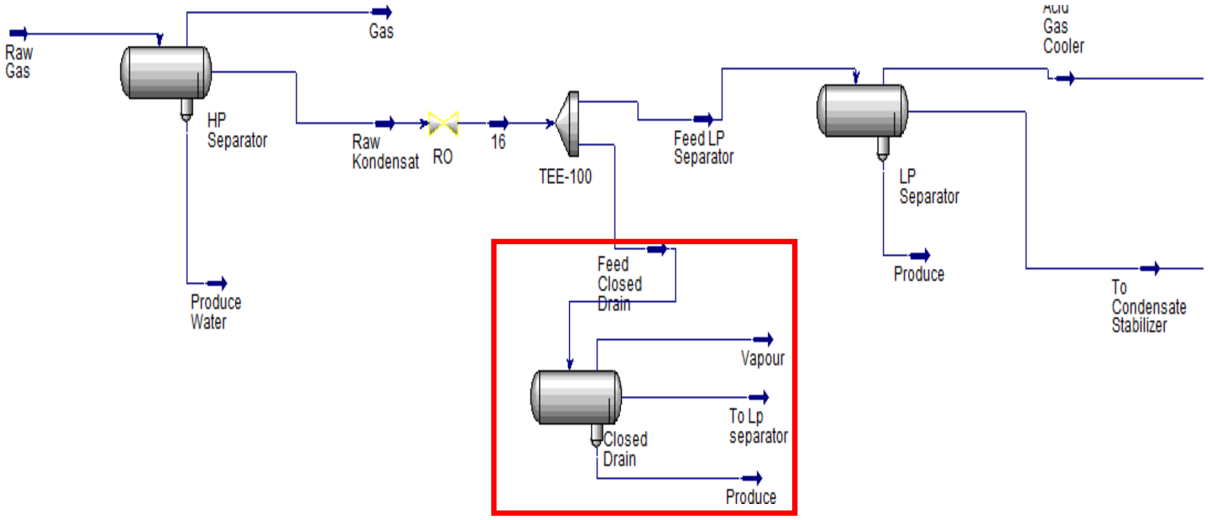
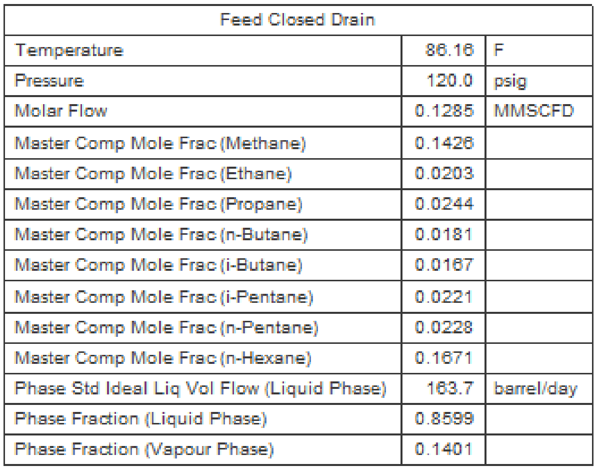


Figure 5. HYSYS Simulation

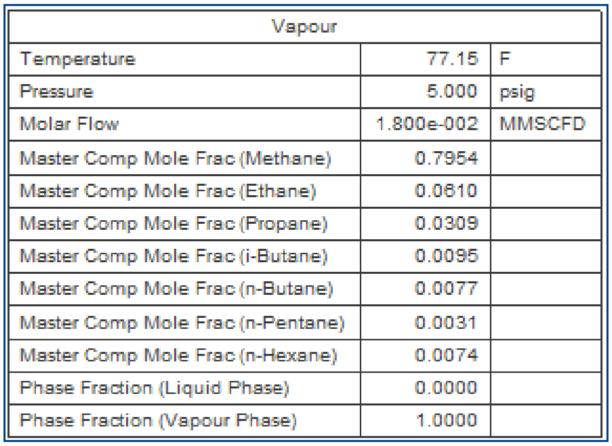
The Hydrocarbon composition of feed Closed Drain as estimated from HYSYS has 86.16˚F, 120 psig, and molar flow of 0.1285 MMSCFD. The composition of feed Closed Drain from the highest mole fraction to lowest are n-hexane, methane, propane, n-pentane, i-pentane, ethane, n-butane, and i-butane. The details of mole fraction value in HYSYS simulation result can be seen in Figure 6.



Feed Closed Drain		
Temperature	86.16	F
Pressure	120.0	psig
Molar Flow	0.1285	MMSCFD
Master Comp Mole Frac (Methane)	0.1426	
Master Comp Mole Frac (Ethane)	0.0203	
Master Comp Mole Frac (Propane)	0.0244	
Master Comp Mole Frac (n-Butane)	0.0181	
Master Comp Mole Frac (i-Butane)	0.0167	
Master Comp Mole Frac (i-Pentane)	0.0221	
Master Comp Mole Frac (n-Pentane)	0.0228	
Master Comp Mole Frac (n-Hexane)	0.1671	
Phase Std Ideal Liq Vol Flow (Liquid Phase)	163.7	barrel/day
Phase Fraction (Liquid Phase)	0.8599	
Phase Fraction (Vapour Phase)	0.1401	

Figure 6. Hydrocarbon Composition of Feed Closed Drain

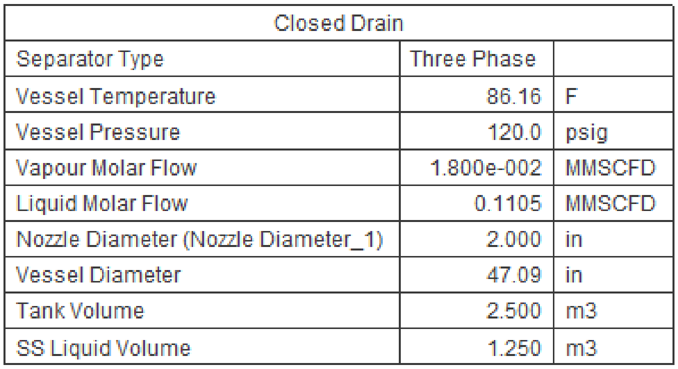
The Hydrocarbon composition of Closed Drain vapour released as estimated from HYSYS has 77.15˚F, 5 psig, and molar flow of 1.800e·002 MMSCFD. The mole fraction of Closed Drain vapour released is dominated by methane up to 0,795. The details of mole fraction from HYSYS simulation result can be seen in Figure 7.



Vapour		
Temperature	77.15	F
Pressure	5.000	psig
Molar Flow	1.800e-002	MMSCFD
Master Comp Mole Frac (Methane)	0.7954	
Master Comp Mole Frac (Ethane)	0.0610	
Master Comp Mole Frac (Propane)	0.0309	
Master Comp Mole Frac (i-Butane)	0.0095	
Master Comp Mole Frac (n-Butane)	0.0077	
Master Comp Mole Frac (n-Pentane)	0.0031	
Master Comp Mole Frac (n-Hexane)	0.0074	
Phase Fraction (Liquid Phase)	0.0000	
Phase Fraction (Vapour Phase)	1.0000	

Figure 7. Hydrocarbon Composition from Closed Drain Vapour Released from HYSYS

After the Hydrocarbon composition of feed Closed Drain and Closed Drain vapour released are being estimated, the nozzle diameter for Closed Drain vapour released is carried out by HYSYS. The specification of nozzle diameter should be 2 inches as seen in Figure 8, while vessel temperature and pressure of nozzle diameter should be 86.16˚F and 120 psig.



Closed Drain		
Separator Type	Three Phase	
Vessel Temperature	86.16	F
Vessel Pressure	120.0	psig
Vapour Molar Flow	1.800e-002	MMSCFD
Liquid Molar Flow	0.1105	MMSCFD
Nozzle Diameter (Nozzle Diameter_1)	2.000	in
Vessel Diameter	47.09	in
Tank Volume	2.500	m3
SS Liquid Volume	1.250	m3

Figure 8. Nozzle Diameter for Closed Drain Vapour Release from HYSYS

Flowline modification design is conducted with 1 piece of weldolet with diameter of 2 to 4 inches, 1 piece of stainless pipe/carbon steel with diameter of 2 inches and length of 2 meters, 1 piece of gate valve with diameter of 2 inches, 2 pieces of flange to flange with diameter of 2 inches, 1 piece of tee, and 2 pieces of elbow with diameter of 2 inches. The vapour trap location is being placed in the 2 inches tee before the gaseous release reaches LP Vent Stack. The flowline modification design can be seen in Figure 9.

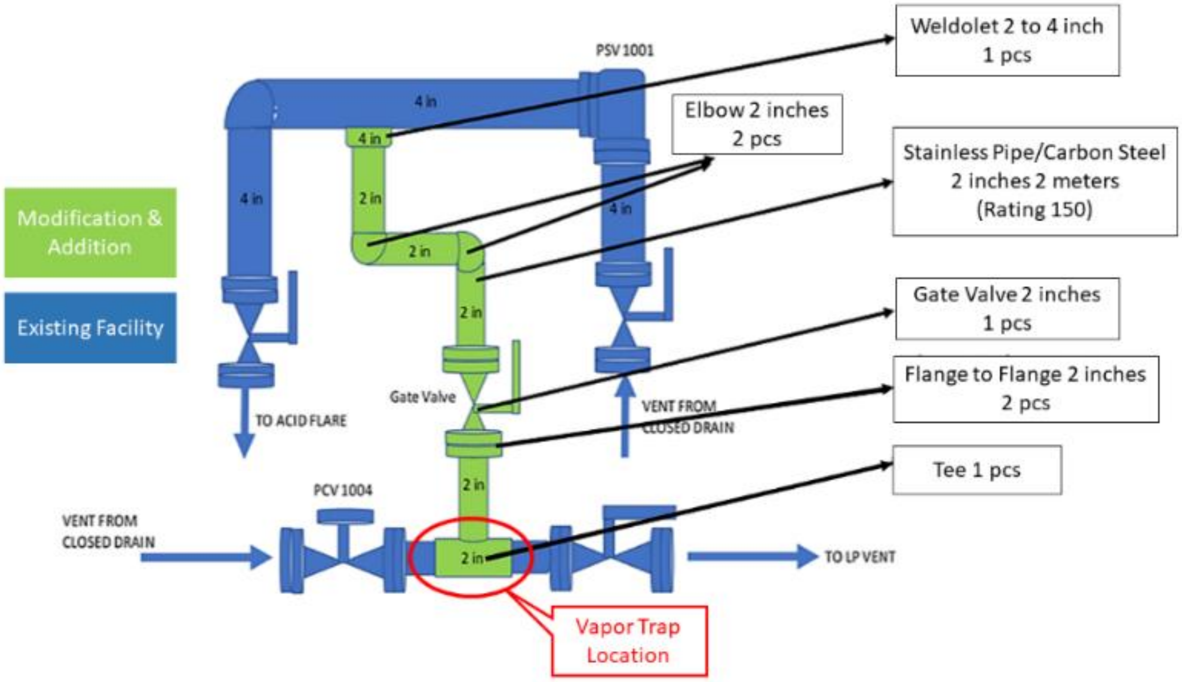


Figure 9. Flowline Modification Design

Flowline modification of Closed Drain vapour to Acid Flare in Matindok CPP reduces emission in LP Vent Stack and affects to subsystem changes resulting in new Standard Operating Procedure (SOP) regarding operating procedure of flowline modification of vapour release flow from Closed Drain to Acid Flare. The condition assessed after flowline modification is implemented also creating energy efficiency, CO_2 emission reduction, and economic benefit.

3.5 Energy Efficiency Leads to CO_2 Emission Reduction

Energy efficiency is gained by the substraction before and after modification is occurred. In this case, energy efficiency resulted from flowline modification of Closed Drain to Acid Flare in Matindok CPP is done by assessing the inventory of total fuel gas flow to Acid Flare from 2022 to 2023. Hence, the energy efficiency and CO_2 emission reduction resulted from flowline modification of Closed Drain vapour to Acid Flare in Matindok CPP can be seen in Table 4.

Table 4. Energy Efficiency and CO_2 Emission Reduction of Flowline Modification of Closed Drain vapour to Acid Flare in Matindok CPP

Year	**Total flow gas to Acid Flare (MMSCF)**	**Energy Efficiency (GJ)**	**CO_2 Emission Reduction (Ton CO_2eq)**
2022	5.5	6,289.91	352.86
2023*	3.65	4,174.21	234.17

*Until June

Economic benefit of implementing flowline modification of Closed Drain vapour to Acid Flare in Matindok CPP is being calculated based on the sales gas, in which this gas is previously used for flare, as according to national gas price. The total economic benefit collected in 2022 is USD 51,445.57 as elaborated in equation below.

Estimated economic benefit

= Own Use Gas Reduction (MMSCF) x 1,037 MMBTU/MMSCF x Gas Price (USD/MMBTU)

= 5.5 MMSCF x 1,037 MMBTU/MMSCF x 9.2 USD/MMBTU

= USD 51,445.57

4. Conclusions

After flame occurred in LP Vent Stack on January and February 2022 at Matindok CPP, flowline modification of Closed Drain to Acid Flare is chosen as solution to prevent future flame and reduce emission in LP Vent Stack. By implementing flowline modification, there is no flame occurred again in Matindok CPP. The gaseous release from Closed Drain is being flowed to Acid Flare as purge, hence reducing the usual purge needed from fuel gas and able to reduce 5.5 MMSCF or equal to reducing CO_2 emission with the amount of 352.86 $kgCO_2$ in 2022 and reduce 3.65 MMSCF or equal to reducing CO2 emission with the amount of 234.17 $kgCO_2$ in 2023. Economic benefit of rerouting Closed Drain to Acid Flare also calculated referring to gas price and estimated to achieve USD 51,445.57 throughout 2022. On the other hand, rerouting Closed Drain to Acid Flare can maintain stability in gas processing facility and improve process safety.

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