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Design Of Blowdown Line LNG Filling Station ISO Tank

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Abstract- *In case of plant efficiency, blow of gas (BOG) waste reduction was studied. At a typical liquefied natural gas (LNG) plant there are threeterminalfor ownership, such as tanker ship facilities and one LNG filling station as a means of filling LNG to ISO tank. A development of bussiness process of plant leads to an increasing in LNG filling station capacity. Along with the plan to increase the filling station capacity, the problem of blow of gas (BOG) wastage along with some LNG to ground flare becomes a serious concern. When the number of fillling stations is only one station, the BOG wasted condition is not significant. However, with plans to increase the number of filling stations, BOG wasted need to be considered to be fully utilized. Therefore, utilizationof the BOG to reachhigher economic value through a design of blowdown line at LNG ISO tank filling station was condsidered. In the design of this blowdown line, 2-inchpipe was interconnected with 6-inchpipe diameter as BOG header of new filling station. For the purpose in designing of BOG line, a thermodynamically and mechanically calculation design was performed. The calculation procedures refer to related standard and codes, such as American Society of Mechanical Engineers (ASME), and Industrial Manual Book. Theresult of the calculation shows that BOG can be utilized. The rate of its evaporation of each ISO LNG tank was 350,958Nm³per charging period.To utilize this BOG, pipeline was designed using BE 40S type SS A312-TP304 SMLS, and insulated with 15 cm-thickness of polyurethane foam block.*

Keywords *–LNG,blowdown Line, filling station, polyurethane, iso tank*

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1. Introduction

Liquid Natural Gas (LNG) is a liquefied natural gas, with composition of 87% - 96% methane, 1,8-5,1% ethan, 0,1-5,1% propane and other compounds. The composition of natural gas (LNG formation) varies depending on the source and the process of its formation. Methane gas in LNG has odorless, non-corrosive and non-toxic properties.Liquifying of gas is basically an alternative method to deliver gas from producer to consumer. When cooled to -162˚C at 1 atm pressure, natural gas becomes liquid and its volume decreases up to 600 times [1]. With such a large volume reduction, liquefied natural gas (LNG) can be transported through the Tanker Ship and the ISO Tank Truck.

A typical LNG Filling Station dispenser can fill up to 6 times in one day,with a maximum LNG loading rate of 20m³/h during ciruculationmode. LNG originates from transfer line with a pressure of 3,5 kg/cm². It will flow in2-inch pipeline until it passes through the bypass line on the up streamfilling station. Furthermore, LNG will be recirculated towards the loop rundown system upgrade (LRSU) which is pressurized to 2 kg/cm². Circulation mode conditionaims to maintain a constant line condition at a range of LNG temperature between -159ºC to -162ºC so that when it is going to be filled into ISO tank, line is ready to be used. In loading mode, LNG originates from transfer line with a pressure of 3,5 kg/cm². It will flow to the 2-inch line to ISO tank. While blow oFgas (BOG) from ISO tank will be drawn through one line by removing LNG along with gas vapor utilizing the pressure difference from ISO tank to ground flare, total LNG burned reaches 1m³/cargo.

In this case the author saw and studied the problem and tried to explain the operational constraints and providedan idea to improve plant efficiency. The idea was implemented in BOG pipelie design.

2. Design Procedure

The design of Blow Of Gas Line LNG ISO tank was performed by steps of: (a) extracting data from plant, (b) collecting properties needs related to state of matter, (c) design calculation,in accordance with the standards and codes of ASMEand the company's Standard Engineering, and (d) conclusion drawn from the calculation.

Data from plant, that was used as input of this calculation, extracted from plant via distributed control system database and from indicated instruments. Properties that related to the state of matter were found from texk books, standard and codes, and another industrial manual books. For calculating, some equation were drawn from standard and codes and text books that conformed

3. Calculation

3.1. Calculation of the Amount of BOG LNG Filling Station Fluid Flow

To perform the calculation of the amount of BOG fluid flow, a set of primary data was extracted from plant. The data was shown at Table 1.

Table 1. Primary Data Time and Pressure

NO	Time (Minute)	Pressure (Bar)
1	1	0,05
2	5	0,4
3	10	0,7
4	15	1
5	20	1,4
6	25	1,7
7	30	2

The data shows that during filling to iso tank, its pressure was increased. This increasing pressure during filling was drawn as a graph that shown at Fig.1. The relation between pressure and time can be modeled by regression of the drawn line, and got an equation y = 0.0667 x + 0.00253. This fitting is valid by R^2 value of 0,9978. This equation could be used to estimate pressure at a specified time.

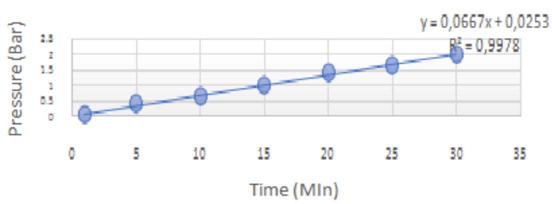

Figure 1. Pressure versus time during iso tank filling

The increasing pressure affects to gas properties, including amount of mol, that important for variable to calculate evaporation rate of gas. The properties were extracted from plant computer and used to determine pipe size and its insulation. The properties and computer calculation was extractred based in one hour, and shown in Table 2 and Table 3.

Table 2. Initial or first condition of gas

First Condition		
P start	1	bar
	1,986923	atm_abs
T start	-159	ºC
	114	K
% Level ISO tank	100	mmH_2O
Volume vapour	17,64705882	m^3
	17647,05882	liter
R	0,0825	liter.atm/mol.K
P x V	=	n x R x T
n	=	(P x V)/(R x T)
n start	=	3728,16024mol

Table 3. Last condition of gas

Last Condition		
P last	5,00453	bar
	5,93908576	atm_abs
T last	-159	ºC
	114	K
% Level ISO tank	100	mmH_2O
Volume vapour	17,6470588	m^3
	17647,0588	liter
R	0,0825	liter.atm/mol.K
P x V	=	n x R x T
n	=	(P x V)/(R x T)
n last	=	11143,79541mol

Density is a properties that take into account in flow rate calculation. Under the condition, density was calculated by the following expression [6], and data in Table 4 and 5.

$$D = A / (B - (Xm * C))$$

Table 4. Value of A for the density equation

Component	Molar (Xi)	Molecular (Mi)	Molecular (Xi * Mi)
CH_4	0,9151	16,0425	14,68
C_2H_6	0,0478	30,069	1,437
C3H8	0,026	44,0956	1,146
I-C4H10	0,0055	58,1222	0,32
N-C4H10	0,0053	58,1222	0,308
I-C5H12	0,0001	72,1488	0,007
N-C5H12	0	72,1488	0
N-C6H14	0	86,1754	0
N2	0,0002	28,0134	0,006
O2	0	31,9988	0
CO2	0	44,0095	0
Total molecular weight (A)			17,904

Table 5. Value of B for the density equation

Molar Volume	Cubic M
(Vi)	(Xi * Vi)
0,03835	0,035094
0,04808	0,002298
0,06261	0,001628
0,07722	0,000425
0,07692	0,000408
0,09124	0,000009
0,09057	0
0,105	0
0,04747	0,000009
0,03171	0
0,02988	0
(B) =	**0,039871**

With the set variables from table:
Liq. Temp. = -159 °C
A = 17.904
B = 0.039871
C = 0.00047
Xm = 0,9151

The density of gas was 453.9 kg/m³.

3.2. Calculation of Average Evaporation Rate

Gas evaporation rate was calculated by plant's computer. The result of the computer can be seen at Tabel 6, from extracted data in a typical period of plant operation.

Table 6. Computer calculation result

Duration of BOG Increase	1	hour
Density LNG	453,9	kg/m³
Delta molFirst - Last	7415,635	mol
Molecular Weight	17,904	
	132769,532	gr
Evaporation Rate LNG	132,770	kg
	132,770	kg/h
	0,283	m³/h
Gas Constant	24,470	
Gas Evaporaton Rate	181460,592	
	181,461	Nm³/h

Table 6 shows the evaporation rate of LNG and gas evaporation rate (BOG) were 0.283 m³/h and 181.461 Nm³/h, subsequently.

3.3 Calculation The Average Rate of Evaporation on Filling LNG ISO Tank

Determining the average evaporation rate when filling is obtained from test data carried out from 18 LNG ISO Tank units in specific one year Period:

- LNG evaporation rate: 0.283 m³ / hour
- BOG evaporation rate: 175,479 Nm³ / Hour

Each ISO Tank requires a charging time of 2 hours, then the evaporation rate during filling into ISO Tank is:

- LNG evaporation rate : 0.566 m³ / hour
- BOG evaporation rate: 350,958 Nm³ / Hour

3.4 Calculation of Pipe Diameter

Pipe diameter was calculated by the equation of [10]

$$D = \sqrt{\frac{4\,Q}{\pi V}}$$

where Q is rate of vapor flow (m³/sec), and V refer to allowable velocity of gas in pipe. The rate of vapor flow was calculated:

$$175.479\ \frac{m^3}{\cancel{hr}}\, x\, \frac{\cancel{1\ hr}}{3600\ sec} = 0.0487\ \frac{m^3}{sec}$$

The allowable gas velocity is based on the Rule of Thumb [8].

$$6000\ \frac{\cancel{ft}}{\cancel{min}}\, x\, \frac{\cancel{1\ min}}{60\ sec}\, x\, \frac{0.3048\ m}{\cancel{1\ ft}} = 30.48\ \frac{m}{sec}$$

Therefore, pipe diameter for the gas flow was:

$$D = \sqrt{\frac{4\,Q}{\pi V}} = \sqrt{\frac{4\ x\ 0.0487}{3.14\ x\ 30.48}} = \sqrt{\frac{0.1948}{95.7072}} = \sqrt{0.00203}$$
$$= 0.045\ m$$

From the calculation above, the nominal diameter of the pipe used is 0.045 m = 45.11 mm = 1.77 inch. Refer to standard and codes [2] and under consideration for LNG plant [3,5,7], a 2 inch pipe diameter was used. The pipeline design of the purpose was decided by general specification. The specification was that for natural gas, liquid nitrogen, and blow of gas are in a specicifaction of PIPE BE 40S SS A312-TP304 SMLS.

3.5 Calculation of Pipe Insulation

Pipe insulation is used to reduce heat loss or heat entry to pipeline system. The types of insulation is depend on the process temperature and ease fabrication. For the BOG pipeline which has temperature of -159 °C, insulation material of polyurethane foam block was chosen.

Besides using the insulation material, alluminium was used to jacketing the insulation material. To maintain gas temperature in selected pipe, thickness of insulation was determined by performing calculation using the equation that provided in the reference book [6,9]. The variables that take into account were served at Table 7.

Table 7. Variables that take into account in insulation calculation

Pipe Material	SS 304
Thermal conductivity pipe	16,3 W/m.K
Od pipe	2,375 inch
Id pipe	2,067 inch
Insulation thickness	10 mm
Insulation Material	*Polyreuthane foam block*
Thermal conductivity insulation	0.018 W/m.K
Material coating / metal jacketing	Alluminium
Coating thickness / metal jacketing	0,24 mm
Thermal conductivity coating	50 W/m.K
Fluida service	LNG
Temperature LNG	-159 ºC
Temperature ambient	38 ºC
Convection heat transfer coefficient (h)	3 W/m.K

The system model for insulation analysis was performed by following sketch.

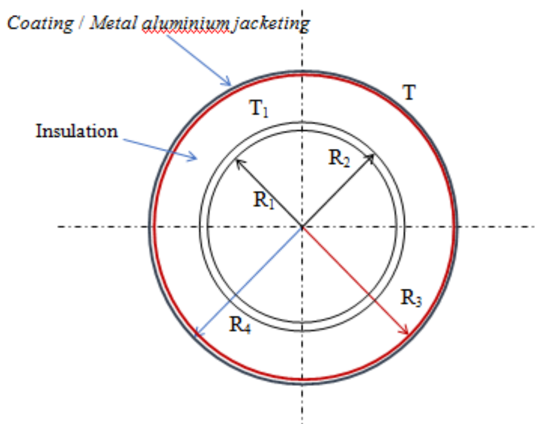

Figure 2. System model of insulated pipe of BOG line

The calculation was performed with the equation [4]:

$$q = \frac{2\pi l(T_4 - T_1)}{\ln(\frac{R_2}{R_1})/k_A + \ln(\frac{R_3}{R_2})/k_b + \ln(\frac{R_4}{R_3})/k_b + \frac{1}{R_4}/h}$$

Where :

$\frac{q}{L}$ = Heat loss per meter lenght

T_4 = Temperature ambient = 38 ºC = 311,15 K

T_1 = Temperature *service* fluid = -159 ºC = 114,15 K

R_1 = RInside pipe = 0,02625 m

R_2 = R outside pipe = 0,03015 m

R_3 = R insulation

R_4 = R*coating*

T_c =*coating thickness* = 0,24 mm = 0,00024 m

k_A = *Thermal conductivity*pipe = 16,3 W/m.k

k_B = *Thermal conductivity*insulation = 0,018 W/m.k

k_C = *Thermal conductivity* coating = 50 W/m.k

h = heat transfer coefficient by convection = 3 W/m.k

T_{insul}=Insulation thickness

The simulation of heat loss per meter length and insulation thickness was performed and the result can be shown at Fig. 3.

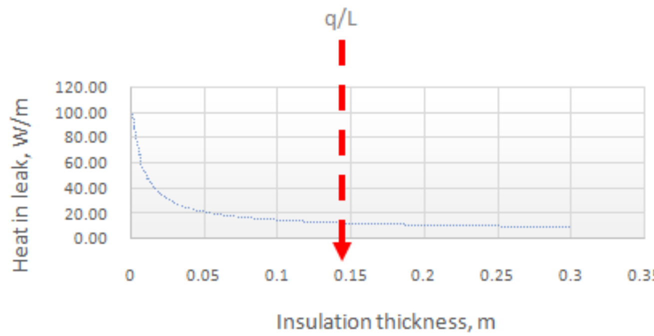

Figure 3. Simulation of heat loss versus insulation thickness

Figure 3 shows that heat loss will be reduced by increasing thickness of insulation. For an acceptance level of heat loss, the insulation thickness was decided in 0.15 m or 15 cm. Heat loss in this thickness was about 10 Watt/m pipe length.

3.5 Calculation of Pipe Support

Pipeline belongs to weight that contributed from pipe weight and its content. This pipeline must be supported to withstands it so that the pipe damaged could be avoided. The damaged could be from initial crack following by creeping until broken [8].

To withstand the pipeline, pipe support must be installed. The number of pipe support and length between support was obtained. The obtaining pipe support, following calculation was performed. The data input for the calculation is shown in Table 8.

Table 8. Data that take into account in pipe support calculation

Data	Spesification	
Nominal Pipe size (NPS)	2	
Schedule	40	
OD (in)	2,375	
ID (in)	2,067	
Thickness (in)	0,154	
Density pipe (lb/in3)	0,289	
Insulation thickness (in)	11,81	30 Cm
Insulation density (lb/in3)	0,0022	50 lb/ft³
Density fluid (lb/in3)	0,016	453,9 kg/m³
Temperature Design (F)	-256	-160 ºC
Pressure Design (psi)	72,52	5 kg/cm²
Safety Factor	4	
Length of pipe (in)	4566	116 m

From the input data, calculation was performed by the following steps and equation [4,10]

$W_{pipe} = \frac{\pi}{4}.(D^2 - d^2).\rho_{pipe}.L$

$= \frac{\pi}{4}(2.375^2 - 2.067^2)\ 0.289 \times 4566$

$= 1417.21$ lb/in or 17074.76 lb/ft

$W_{fluid} = \frac{\pi}{4}.(d^2).\rho_{fluid}.L$

$= \frac{\pi}{4}(2.067^2) \times 0.016 \times 4566$

$= 245.02$ lb/in or 2952.08 lb/ft

$W_{insulation} = \frac{\pi}{4}.(D^2\ ins - D^2).\rho\ ins.L$

$= \frac{\pi}{4}(11.81^2 - 2.375^2) \times 0.0022 \times 4566$

$= 1055.36$ lb/in or 12715.15 lb/ft

$W_{total} = W_{pipe} + W_{fluid} + W_{insulation}$

$= 2717.59$ lb/in atau 32741.99 lb/ft

Based On Deflection Limits :

$$LS = \frac{\sqrt[4]{\Delta \times E \times I}}{22{,}5 \times w}$$

$$LS = \frac{\sqrt[4]{\frac{3}{8} 30.3x10^6 \times 6.6^4}}{22{,}5 \times 2717{,}59}$$

LS = 9.93 ftor 3 m

Pipe span = Length pipe / *LS*
= 116 m / 3 m
= 38.6

The total number of BOG line pipe supports with a length of 116 meters based on deflection limits used is 38 pieces with a distance between pipe supports was 3 meters. The illustration of pipe span can be seen at Fig. 4.

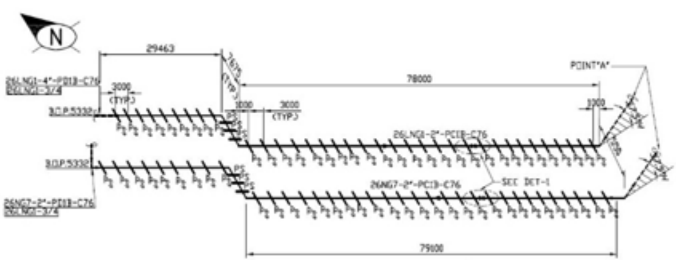

Figure 4. Pipe span support

The all calculation result were used as a based to engineering drawing. Parts of the drawing were served at Fig. 5 and Fig. 6.

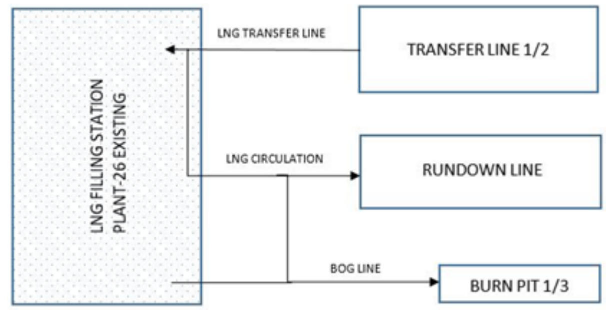

Figure 5. BOG to burnpit block diagram

Figure 5 shows that BOG still thrown into the burn pit, causing LNG to be wasted every time it empties the circulation line.

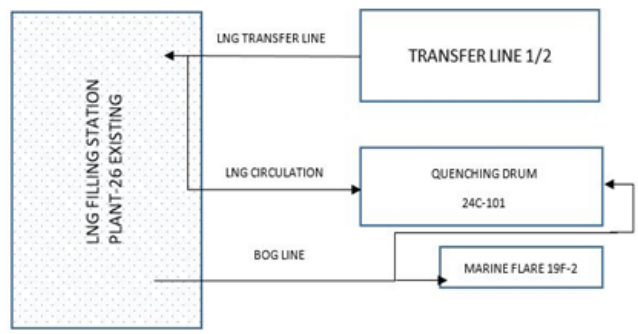

Figure 6. BOG to quenching to recovery block diagram

Figure 6showsa diagram of BOG line that has been connected to Marine Flare and Quenching system so that the BOG formed during the loading process can be drawn towards the quenching system which is then flowed into fuel gas as boiler feed.

4. Conclusions

1. Liquid Natural Gas (LNG) is energy that cannot be renewed (fossil energy) so that it needs to be used more effectively to get better economic value for the company.
2. LNG Filling station at company is designed with a BOG line that leads to ground flares to be burned.
3. The rate of evaporation of LNG at each ISO LNG Tank is 0.283 m^3 / hour, and for 2 hours of filling is 0.566 m^3 / hour.
4. The BOG Evaporation rate of each ISO Tank LNG filling is 175,479 Nm^3 / Hour, and for 2 hours the charging takes place at 350,958 Nm^3 / Hour.
5. Diameter of the pipe to be used adjusts the demand for Process Engineering based on the Job Study of Transmittal LNG Filling Station is PIPE BE 40S type SS A312-TP304 SMLS.
6. Based on the theoretical estimation of insulation with a thickness of 0.15 m (15 cm), it is good enough to insulate the pipe so that the heat in leak does not occur from the environment to the fluid inside the pipe.
7. The number of BOG line pipe supports with a length of 116 meters based on the theoretical deflection limits

used is 38 pieces with a distance between the pipe supports is 3 meters.

5. Recommendations

1. It is necessary to further study the steps in utilizing LNG LNG Tank Blow of Gas.
2. In order to increase the utilization of BOG from ISO Tank, it is necessary to add a pipeline that is capable of flowing BOG to the main inlet pipe line leading to the BOG compressor (24K-1/8 / 9/16) so that it can be used as fuel for Gas Boilers and Turbines with designs that pay attention to safety aspects and according to company standards.
3. Need a more in-depth study in analyzing pipeline conditions related to stress analysis and flexibility analysis.

6. Acknowledgment

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