# Process Diagnosis of LNG Regasification Terminal Pipeline

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ABSTRACT

Gas production capacity requirement to Pyeong-Taek LNG receiving terminal I which started operations in 1986 has been increased continuously for 27 years due to rapid increase of domestic gas consumption rates in Korea. Regardless of early capacity design concept, many expansion works for supplying more production demands have been implemented with new pipelines attached to existed pipeline. Nowadays, the specific diagnosis is needed to see if the rated performance of process system can be achieved or not, through various and complicated pipeline configurations to be added and modified for decades. High pressure LNG pumps may be classified to three types of performance curves groups. Also, vaporizers have different production capacities. The sizes of the header pipes are not uniform and designed to fit design flow rates of branch pipes respectively. In view of hydraulics, the fact is that unbalanced pipeline system have limitations when it try to distribute required flows properly into many branched pipelines. Also those phenomenon have been occasionally observed on-site. Therefore hydraulic analysis using commercial pipe network analysis tool were carried out due to complexity and numerous variables of analysis.

Process diagnosis of unloading pipeline and high pressure pipeline system were carried out to review real performance of process system and estimation of the production capacities worn-out due to the past long-term operation, finally to find improvement measures of operational reliability through the re-analysis. Modelings of unloading pipelines and high pressure LNG sendout system were performed referring directly several hundred pieces of isometric drawings in detail and considering elbows, valves characteristics, pipe lengths, pipe sizes, elevations, pipe connection shape and so on. The target of analysis is to check if LNG sendout pipeline system can be enough to supply high pressure LNG flow of 2,296 ton/hr which is maximum design sendout rate of LNG regasification facilities in Pyeong-Taek terminal I, 2012. The various scenarios were simulated with improvements such as pipe size changes, another pump installation, and so on.

KEY WORDS: LNG; Pipeline; Sendout Capacity; Regasification; Hydraulic Analysis

NOMENCLATURE

| | |
|---|---|
| LNG | liquefied natural gas |
| HP | high pressure |
| PT I | Pyeong-Taek receiving terminal I |

## INTRODUCTION

Pyeong-Taek terminal I which started operating in 1986 needed a diagnosis on massive facilities added step by step, in order to supply additional production requirements due to rapid increase of domestic gas consumption rates in Korea. LNG densities have been diversified due to the diversification of import localities for decades. The diversification has changed facilities operating conditions and production performances. Total piping system has been expanded and complicated from many extension works. Nowadays, the specific diagnosis is needed to see if the rated performance of process system can be achieved or not, through various and complicated pipeline configurations.

Process diagnosis on high pressure LNG pipeline system and unloading pipeline were carried out to review a real performance of the worn-out process system and estimation of the possible production capacities due to the past long-term operation, finally to find improvement measures of operational reliability through re-analysis. Figure 1. shows the unloading and sendout pipeline configuration conceptually.

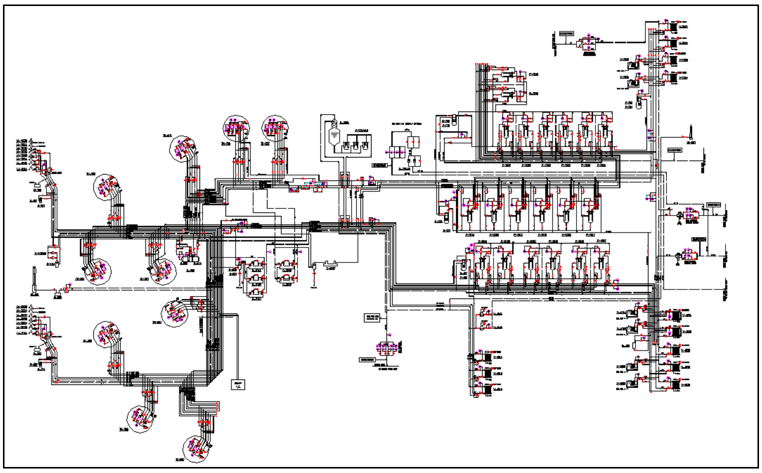

Figure 1. Conceptual pipeline configuration of PT I

## UNLOADING PIPELINE HYDRAULIC ANALYSIS

Using unloading arms connect LNG cargo ship and on-shore terminal, LNG is transported and stored into LNG storage tanks(TK-201,202,304,205,706,707,308,309,310 in Pyeong-Taek terminal I). Pyeong-Taek terminal I has two docks (I, II). The dock I has four 16" unloading arms (LA-101A/B/C/D, D is spare) and the dock II has three 16" unloading arms (LA-301A/B/C). Those arms have the capacity of 3,740 $m^3$/hr in normal operation, respectively. Normal unloading flow rate is designed to 11,000 $m^3$/hr using three LNG unloading arms and one vapour return arm. In the normal unloading operation, LNG is unloaded to two LNG storage tanks through two 30-inch unloading header pipelines at a flow rate of 11,000 $m^3$/hr (5,500 $m^3$/hr, 50% a pipeline). In the abnormal condition, LNG is unloaded at a flow rate of 8,250 $m^3$/hr (75%) by using only one unloading header pipeline. For hydraulic analysis of unloading pipelines, 24-inch unloading pipelines from unloading arms, two 30" headers, two 32" headers, and 24" pipelines up to inlet fill nozzle on the top of tanks are modeled in detail by FLOWMASTER V7.8 and checking directly several hundreds of Isometric pipe drawings. Finally all piping, valves, and fittings are described based on the data of piping sizes, lengths, and elevations. Only one unloading piping system was modeled and simulated because two parallel pipelines have same configuration. The objective of unloading hydraulic analysis is to make sure if LNG can be unloaded into each tank in normal or abnormal condition. Figure 2. shows unloading pipeline system configuration.

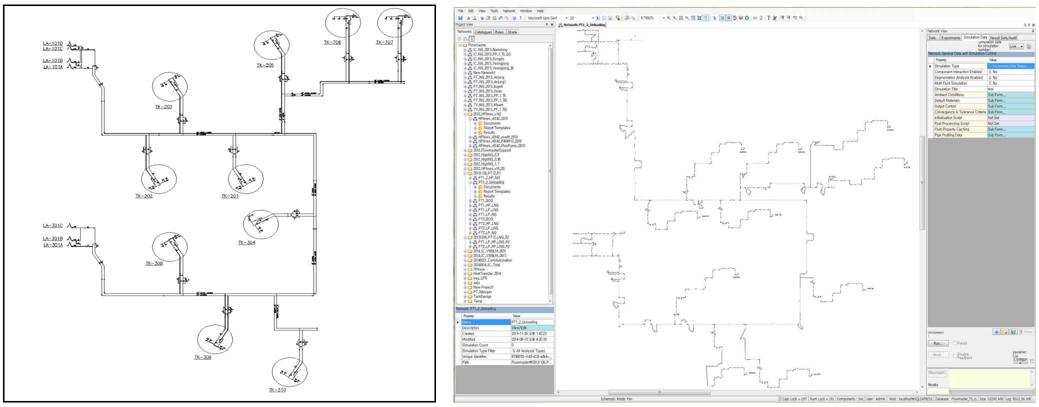

Figure 2. Unloading pipeline system configuration and modeling in PT I

Analysis conditions are as follows;

1) Design unloading flowrate : 11,000 $m^3$/hr
2) LNG Density
  - Lean Case : 434 kg/$m^3$
  - Rich Case : 478 kg/$m^3$
  - Typical Case : 455 kg/$m^3$
3) Pressure at the ship flange [design condition]: 5.54 kg/$cm^2$ (4.42 bar)
4) Tank operation pressure : 0.1937 kg/$cm^2$ (0.19 bar)
5) Normal LNG unloading condition :
  - Unloading flow rate: 11,000 $m^3$/hr using two headers
  - 5,500 $m^3$/hr a tank (LNG is transported to 2 tanks).
6) Abnormal LNG unloading condition :
  - Unloading flow rate : 8,250 $m^3$/hr(75% of 11,000 $m^3$/hr) using a header.
  - 8,250 m3/hr a tank (LNG is transported to a tank)

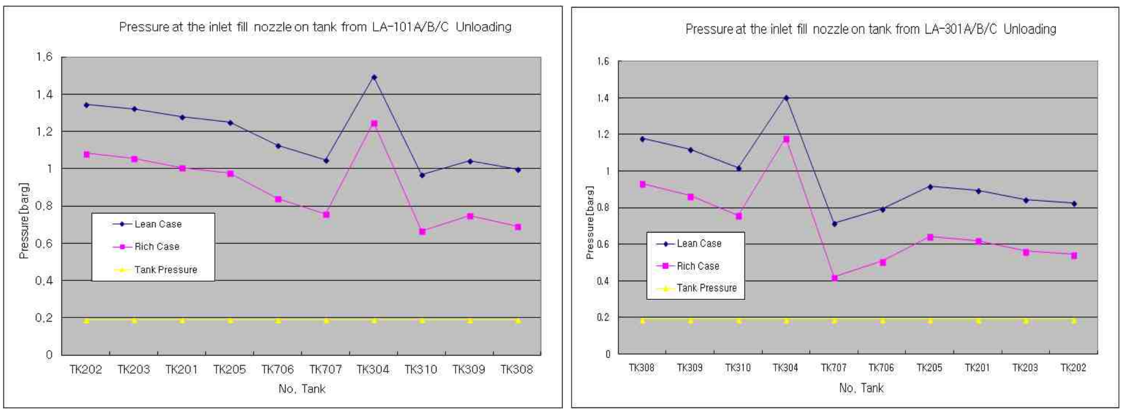


Figure 3. Pressures at the inlet fill into tanks when unloaded from dock I and II respectively [Normal Operation]

Figure 3. shows us pressures at the inlet fill into tanks are more than 0.19 bar [internal pressure in tank]. That means it is available to unload LNG at the flow rate of 11,000 $m^3$/hr into two tanks which has inlet flow rate of 5,500 $m^3$/hr respectively, in normal operation condition.

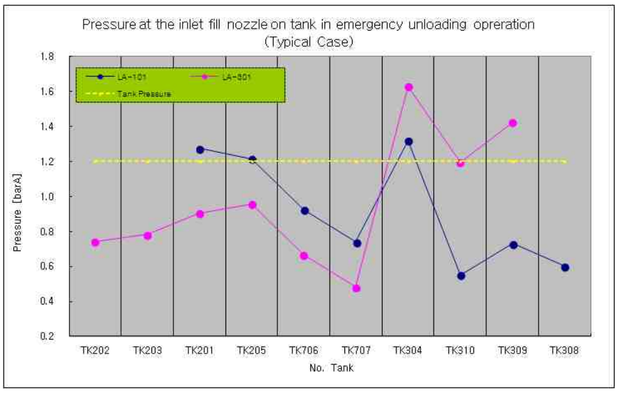


Figure 4. Pressure at the inlet fill into tanks when unloaded from dock I or II respectively [Abnormal Operation]

Figure 4. shows us pressures at the inlet fill into tanks are more than 0.19 bar(1.2 bar A) in cases of LNG transportation into TK202, 203, 201, 205, 304 using LA-101 A/B/C on the dock I and LNG transportation into TK308, 309, 304 using LA-301 A/B/C on the dock II. In abnormal operation condition, it is not available to transport LNG into TK-706, 707, 310, 309, 308 using LA-101 A/B/C on the dock I and LNG into TK-202, 203, 201, 205, 706, 707, 310 using LA-301 A/B/C on the dock II. If LNG should be transported into tanks not available in abnormal condition, alternatively it is necessary to disperse unloading flow into two tanks so that each tank has unloading flow rate of 4,125 $m^3$/hr.

Compared with other tanks, TK-304 has lower tank level elevation by 8.55m uniquely. Even if it has longer pipeline length, there are no difficulties when LNG be unloaded into TK-304 in case of normal and abnormal condition.

## HP LNG SENDOUT PIPELINE ANALYSIS

Referring to several hundreds of isometric drawings, HP sendout piping system from HP pumps to suction pipes of HP vaporisers was examined and modeled. All piping, valves, and fittings are described based on the data of piping sizes, lengths, locations, and elevations. The sendout rates, pipe sizes, and rated flow rates of HP pumps and vaporisers are shown in Table 1. Detailed pipeline configuration of HP LNG sendout and analysis model are shown in Figure 5.

Table 1. HP sendout facilities in PT I

| Items | | Diameter[1)] | ea | Rated Flowrate [$m^3$/hr] | Rated Flowrate [T/hr] | Total Sendout Rate |
|---|---|---|---|---|---|---|
| HP pumps (23 ea) | P404 A~F | 10"(6")[2)] | 6 | 168.6 | 77 | 5176 $m^3$/hr [2355 T/hr] |
| | P404 G~I | 10"(6")[2)] | 3 | 260.0 | 118 | |
| | P701 A~F | 16"(8")[2)] | 6 | 241.8 | 110 | |
| | P702 A~H | 16"(8")[2)] | 8 | 241.8 | 110 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| HP Vaporiser (17ea) | V402 A/B | 8″ | 2 | 395.6 | 180 | 5046 $m^3$/hr [2296 T/hr] |
| | V402 C~E | 10″ | 3 | 395.6 | 180 | |
| | V701 A~D | 10″ | 4 | 395.6 | 180 | |
| | V403 A/B | 6″ | 2 | 149.5 | 68 | |
| | V403 C/D | 8″ | 2 | 197.8 | 90 | |
| | V702 A/B | 8″ | 2 | 197.8 | 90 | |
| | V702 C/D | 6″ | 2 | 197.8 | 90 | |

1) HP header size about HP pumps, Suction pipe size about vaporisers.
2) ( ) means that HP pumps outlet pipe size connected to HP Header

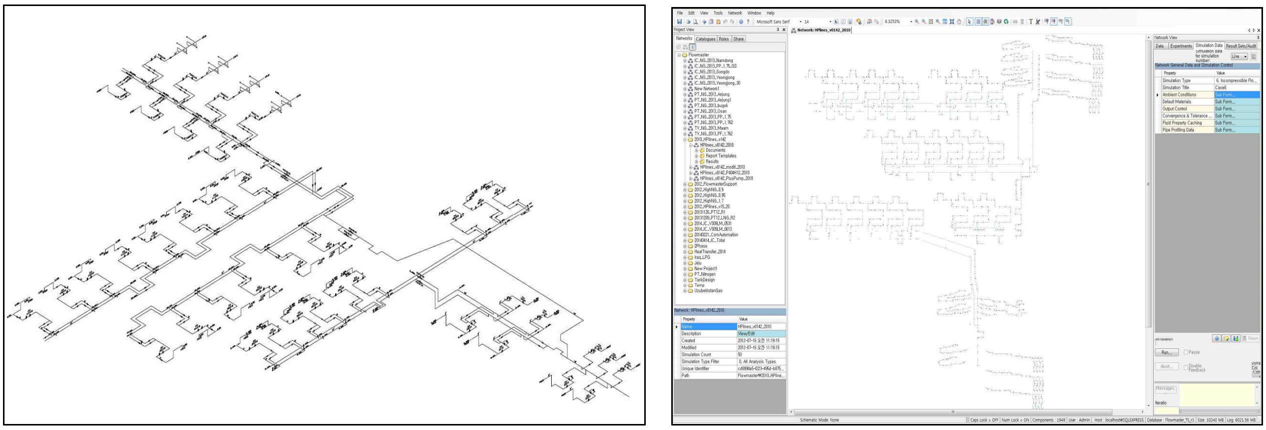

Figure 5. Detailed pipeline layout of HP LNG sendout piping network in PT I & Modeling by FLOWMASTER v7.8

The objective of HP sendout piping hydraulic analysis is to determine if it is possible to make a sufficient HP LNG flows to vaporisers by HP pumps, in order to meet design capacity of 2296 ton/hr which means that all HP vaporisers should be operated. HP pumps may be classified into three types such as P404 A~F, P404 G~I, and P701A~F & P702 A~H as shown in figure 6. Three types of HP pumps have different performance curves respectively. And as figure 5. show, HP sendout pipeline layout is very complicated due to many pipeline extension works during the past several decades. It is not available to calculate pressure profiles without computing device usage because of pipe network complexity.


Figure 6 HP pumps Performance Curves

Analysis conditions are as follows;

1) Design flow rate is 2296 Ton/hr (5046 $m^3$/hr).
2) Assumed that all 17 vaporiser units be operated (5046 $m^3$/hr)
3) Assumed that all 23 HP pump units be operated (5176 $m^3$/hr)
4) Density of LNG : 455 kg/$m^3$
5) Vaporisers suction pressure : 75.4 kg/$cm^2$ (normal operation pressure)
6) HP pump suction pressures : 10.1 kg/$cm^2$

Six cases analyzed are as follows;

1) Case 1 : Current condition without options
2) Case 2 : Vaporisers suction pressure : 74.4 kg/$cm^2$ setting (lower than normal operation pressure by 1 kg/$cm^2$)
3) Case 3 : V403 A/B, V702 C/D inlet pipe size 6" ⇒ 8" changed option
4) Case 4 : P404 series header size 10" ⇒ 12" changed option
5) Case 5 : New P702 I attached (HP pumps X 24ea operated)
6) Case 6 : V701 D vaporiser shutdown

The criteria about whether HP pumps supply sufficient flows to HP vaporisers is to check the calculated flow rates reach the rated flow rates of HP vaporisers.

Table 2. Simulation results in cases

| Item | Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6 |
|---|---|---|---|---|---|---|
| No. of HP pumps operated | All | All | All | All | All+P702I [Added] | All |
| No. of Vaporisers operated | All | All | All | All | All | V701D Shutdown |
| V403A/B, V702C/D Inlet pipe diameter size[1)] | 6″ | 6″ | 8″ (Changed) | 6″ | 6″ | 6″ |
| P404 line Header pipe size | 10″ | 10″ | 10″ | 12″ (Changed) | 10″ | 10″ |
| Vaporiser inlet pressure [kg/$cm^2$] | 75.4 | 74.4 | 75.4 | 75.4 | 75.4 | 75.4 |
| Required total flow | 2296 | 2296 | 2296 | 2296 | 2296 | 2116 |
| Calculated total flow | *2227* | 2296 | *2230* | *2236* | 2296 | 2116 |

1) The other vaporiser suction inlet pipe sizes are 8" normally.

In case 1, the calculated flow values don't reach the rated flow rate of V402 A/B, V403 A/B, V702 C/D and HP pumps all send flow rates less than the rated. It is not possible to provide sufficient flow even if all HP pumps run. Estimated total flow rate is 2227 ton/hr and △69 ton/hr flow is insufficient to meet required total capacity. For case 2, the calculated flow values reach the rated flow rates of HP vaporisers. When it is operating with suction pressure of vaporiser lower than 75.4 kg/$cm^2$, it is available to make required flows. In case 3, it was shown as similar results of case 1 even if V403 A/B and V702 C/D suction pipe sizes take 8" a step up. Estimated total flow rate is 2230 ton/hr and △66 ton/hr flow is insufficient to meet required total capacity. In case 4, even if P404 series header size take 12" a step up, the calculated total flow doesn't meet the required total flow. In cases of 5 and 6, required total flows are satisfied with new a HP pump installation or a vaporiser's shutdown. but the case 6 is not in design capacity operation mode.

When compared the total capacity of HP vaporisers with total capacity of HP pumps, an excess of HP pumps performance is 59 t/h. In view of operability and reliability, it is recommended that an excess of HP pumps performance should be increased more than a HP pump capacity [110 t/h].

## CONCLUSIONS

An unplanned equipment installations due to rapid increase of domestic gas consumption in Korea and aged facilities over 27 years has made Pyeong-Taek terminal I performances declined and HP sendout piping configuration very complicated. Nowadays, the requirements for renewal design of HP sendout piping network and diagnosis about real performance expectations of regasification system have been increased continuously and more analytical supports has been invested.

Regardless of early design capacity concepts, lots of pumps and piping attachments on existed headers make total performance of piping network unexpected or lower. In case of Pyeong-Taek terminal I which has carried out much extension works for many years, it is necessary to estimate the performance and to make improvement measures efficiently, through proper technical analysis.

This study gave us to understand the complicated flow patterns and pressure profiles on unloading and HP send out pipe networks, and gave ideas about the system's performance improvements. In addition, the feed or basic designs considering long term expansion plan will protect the performance of system from being declined.

## REFERENCES


- Ha Jong Mann, et al. (2009). "Comparison analysis of process facilities, operation features in each LNG receiving terminal, and the application of the optimized operation in pumps." KOGAS R&D Report, South of KOREA
- "Gas Production Technology Note Rev.3", (2007), KOGAS Internal Data Book, South of KOREA
- E. Shashi Menon, (2004), "Liquid Pipeline Hydraulics", Marcel Dekker Inc.
- J. Paul Tullis, (1989), "Hydraulics of Pipelines", John Wiley & Sons Inc.
- Flowmaster V7 Reference Help, (2013), Mentor Graphics.