SUSTAINABILITY APPROACH IN MODELING AND IMPROVEMENT OF FINGER TYPE SLUG CATCHER IN GAS PROCESSING PLANT

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ABSTRACT

This thesis studies the slug flow behavior inside a finger type slug catcher. Slug exists when two phases are flowing together. Slug can cause damage and unnecessary shut down of process equipment. To handle slug, finger type slug catcher is used as a liquid receiving facility designed to handle large volume of liquid and to stabilize it. Finger type slug catcher used the gravity settling separation method to separate the gas and liquid phase of the flow. Finger type slug catcher can be massive in size, and the gas recovery percentage is difficult to maximize. Unbalanced mass distribution of the natural gas inside the slug catcher contributes to the low gas recovery inside the slug catcher. The objective of this research is to increase the mass distribution of the flow on the original slug catcher design hence increasing the efficiency of the separation. A base model is designed for the original finger type slug catcher using Gambit and several modifications can be added from there named modify design. The proposed modification for the original slug catcher design is the addition of one equalizer header and the T-junction separation at inlet manifold. Original and modified slug catcher designs are tested for its efficiency by using Fluent. Both the velocity magnitude and phase volume fraction will be taken as result to compare the effectiveness of the modification. Result from the original slug catcher design show an unbalanced mass distribution by analyzing its velocity magnitude. Poor separation cause by both the unbalance mass distribution and unsuitable pressure inside the original slug catcher lead to low separation of gas. Modify design of the slug catcher show a positive response of the velocity magnitude and suitable pressure on the inlet manifold. T-junction separation at inlet manifold cause the velocity magnitude to be even on both of the pipe and mass distribution balance are greatly increased. The modifications of the original design thus increase the effectives of finger type slug catcher by 6%.

ABSTRAK

Tesis ini membentangkan tentang pergerakan dan perlakuan slug didalam penangkap slug jenis jejari. Slug terbentuk apabila dua fasa mengalir serentak. Slug boleh menyebabkan kerosakan dan peralatan ditutup secara tidak dirancang. Untuk mengatasi slug, penangkap slug jenis jejari digunakan kerana ianya adalah sebuah alat untuk menerima cecair didalam jumlah yang banyak dan menstabilkan cecair tersebut. Penangkap slug jenis jejari mengunakan teknik pemisahan pemendapan graviti untuk mengasingkan fasa gas dan fasa cecair. Direka didalam bentuk dan saiz yang besar, penangkap slug jenis jejari mempunyai peratusan yang sukar untuk dimaksimumkan. Pergerakan jisim gas asli yang tidak seimbang menyumbang kepada pemulihan gas yang rendah di dalam penangkap slug. Objektif kajian ini adalah untuk meningkatkan taburan jisim pengaliran pada reka bentuk asal penangkap slug justeru meningkatkan keberkesanan/efisiensi pengasingan. Asas model reka bentuk untuk penangkap slug jenis jejari pada asalnya adalah menggunakan gambit dan beberapa pengubahsuaian dan penambahan dilakukan yang dinamakan mengubah suaikan reka bentuk. Pengubahsuaian yang dicadangkan untuk reka bentuk asal penangkap slug jenis jejari adalah dengan menambah satu penyama di kepala dan pengasingan di persimpangan T pada pancarongga masuk. Reka bentuk asal dan penangkap slug yg diubahsuai diuji kecekapannya dengan menggunakan fasih. Keputusan dari reka bentuk asal penangkap slug menunjukkan taburan jisim yang tidak seimbang daripada analisa magnitude halajunya. Pemisahan yang lemah disebabkan oleh kedua dua taburan jisim yang tak seimbang dan tekanan yang tidak sesuai di dalam penangkap asal slug menyebabkan pemisahan gas yang rendah. Reka bentuk penangkap slug yang diubahsuai menunjukkan tindak balas yang positif terhadap magnitude halaju dan tekanan yang sesuai pada pancarongga masuk. Pemisahan persimpangan T di pancarongga masuk menyebabkan magnitude halaju menjadi adil terhadap kedua-dua paip dan baki taburan jisim bertambah denagn banyaknya. Pengubahsuaian dari reka bentuk asal sekali gus meningkatkan keberkesanan penangkap slug jenis jejari sebanyak 6%.

TABLE OF CONTENTS

Page

SUPERVISOR'S DECLRATION

STUDENT'S DECLARATION

ACKNOWLEDGEMENTS i

ABSTRACT ii

ABSTRAK iii

TABLE OF CONTENTS iv

LIST OF TABLES vii

LIST OF FIGURES viii

CHAPTER 1 INTRODUCTION

1.1	Introduction	1
	1.1.1 Main Process Section of Full Well Stream	6
	1.1.2 Crude Oil and Natural Gas	7
1.2	Problem Statement	8
1.3	Objectives	8
1.4	Scope of Study	9
1.5	Rationale and Significance	9

CHAPTER 2 LITERATURE REVIEW

2.1.	Slug in Long Pipeline	10
	2.1.1. Hydrodynamic slugging	10
	2.1.2. Elevation slugging	11
2.2.	Separation	11
2.3.	Slug Catcher	12
2.4.	Sizing Factor for Finger Type Slug Catcher	13
	2.4.1. Finger Type Slug Catcher	14
	2.4.2. General Design Aspect of Finger Type Slug Catcher	16
2.5.	Mass Flow Inside Finger Type Slug Catcher	18
2.6.	Possible Approach in Improvement of Finger Type Slug Catcher	21
2.7.	Previous Work Done by Researchers	24

CHAPTER 3 METHODOLOGY

3.1.	Introduction	25
3.2.	Identify Type of Contaminations	26
3.3.	Data Enquiry	26
3.4.	Simplify the Process	29
3.5.	Indentifying Possible Modification	29
	3.5.1. Tee-junction separator at inlet manifold	32
	3.5.2. Equalizer Head	32
3.6.	Simulation runs using Gambit	33
3.7.	Simulation runs using Fluent	33
3.8.	Analysis of Test Simulation	35

CHAPTER 4 EXPECTED RESULT

4.1	Introduction	36
4.2	Original Design Boundary Simulation Result	36
4.3	Modify Slug Catcher Simulation Result	39
4.4	Comparison and Discussion of Both Slug Catcher Design Simulation	41
	4.4.1. Gas Phase Volume Fraction Comparison	41
	4.4.2. Total Pressure Comparison	42
	4.4.3. Velocity Magnitude Comparison	43
	4.4.4. Data Comparison	45

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS

4.5	Conclusion	47
4.6	Recommendation for the Future Research	48

REFERENCES 49

LIST OF TABLES

Table No.	Title	Page
3.1	Essential data for Gambit	27
3.2	Fluent setting	34
4.1	Comparison of value from both slug catcher design	45

LIST OF FIGURES

Figure No.	Title	Page
1.1	The formation of natural gas	2
1.2	Type of oil and gas reservoir trap inside	4
1.3	The terrain-induced slugging	5
2.1	Slug catcher	13
2.2	Finger-type slug catchers at Den Helder, The Netherlands	15
2.3	General design of finger type slug catcher	17
2.4	Simulated even mass flow inside slug catcher	19
2.5	Different two phase pattern in horizontal pipe	20
2.6	Tee-junction separation at inlet manifold	22
2.7	Equalizer header in finger type slug catcher	23
3.1	Top view original design slug catcher	27
3.2	Side view of original design slug catcher	28
3.3	Gas outlet and liquid outlet for slug catcher	2 8
3.4	Top view of the location of modification	30
3.5	Top view of the modify slug catcher	31
3.6	Side view of modify slug catcher	32
4.1	Original design volume fraction	37
4.2	Original design total pressure	38
4.3	Original design velocity magnitude	38
4.4	Modify design volume fraction	39
4.5	Modify design total pressure	40
4.6	Modify design velocity magnitude	40

LIST OF APPENDICES

Appendix	Title	Page
A-1	Overall Process at Onshore Gas Terminal Kertih	51
A-2	Onshore Gas Terminal Kertih Raw Natural Gas Compostion	52

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Natural gas is a type of fossil fuel because most scientists believe that natural gas was formed from the remains of tiny sea animals and plants that died 200-400 million years ago. Thus it is considered a non-renewable fossil fuel.

With its benefits, comes much processes and treatments that are needed to harness this form of energy source. To put aside more simply, natural gas has many contamination such as acid gas H_2S, mercury and CO_2. As it is being explained before, natural gas is drilled from the earth carrying natural gas. Natural gas itself has low dew point. To transport the natural gas from the offshore production to the Gas Terminal, we use pipeline. (Project, 2004)

Natural gas used by consumer mostly composed with entirely of methane. Industry term for this is sales gas. Although natural gas is composed entirely of methane, it is not

primary pure. There are three type of well in which natural gas comes from, which is oil wells, gas wells, and condensate wells. From figure 1.1, from the timeline of 400 million years ago, when the animals and the sea plant died, a layer of sedimentary mud and rock covers its remains and buried them.

Oil and Natural Gas Formation

Tiny plants and animal died and were buried on the ocean floor. Over time, they were covered by layers of sedimentary rock

Over millions of years, the remains were buried deeper and deeper. The enormous heat and pressure turned them into oil and gas

Today, we drill down through layers of sedimentary rock to reach the rock formations that contain oil and gas deposit

Figure 1.1: The formation of crude oil and natural gas

Source: (Mokhatab, 2006)

With constant process of sedimentary layers, these remains are buried deeper to the point which they received enormous pressure. Societies believe that with high pressure combine with heat of the earth, the remains which is an organic matter is transform into petroleum and natural gas. Being buried with rock and dirt, concentrations of natural gas became trapped in the rock layers like wet sponge traps water. This area is what we called an oil and gas reservoirs.

From an oil wells reservoir, natural gas that comes from these reservoirs is called associated gas. This gas can either be trapped in the oil which is called dissolved gas because the natural gas is dissolved inside the oil. If the gas can exist separately from the oil, it is called free gas. Non-associated gases are called for natural gas from a gas and condensate wells because there is little to no crude oil in the reservoir. Gas wells typically produce only raw natural gas. While condensate wells in another hand produce free natural gas along with a semi-liquid hydrocarbon condensate. (Devold, 2009)

The oil and gas bearing structure is typically of porous rock. For example, sandstone or washed out limestone. For oil reservoir to form, a combination of porous rock and non-porous layer which is salt or mud is needed. As tectonic movement made the rock structure folded and rose, the hydrocarbon migrate out of the deposit and upward in porous rock and collect in chest under the non-permeable rock. The figure 1.2 shows the foundation layer of oil reservoirs.

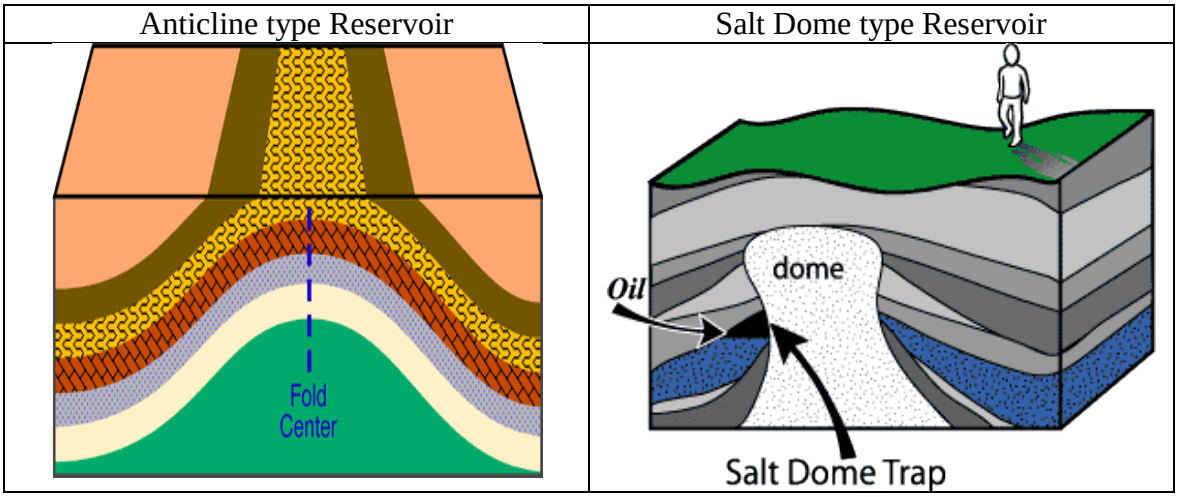

Figure 1.2: Type of oil and gas reservoir trap inside

Source: (Devold, 2009)

In the pipeline, pressure drop and energy transfer happen. For energy transfer, the cool surrounding temperature make the natural gas turn into two phase flow. The heavier hydrocarbons of the natural gas which is C5 and above turn from gas form to liquid form, thus creating a two phase flow inside the pipeline. The phenomenon is called slugging.

Slugging is the effect of two phase flow between gas and liquid. Gas flow much faster than liquid and under certain operating condition, the gas and liquid flow are not evenly distributed throughout the pipeline. Rather it travels in large plugs with the influence of gravity. Basically there are plugs of liquid with gas in between and traveling in the pipeline.

In the figure 1.2, we see an example of a terrain induced slugging. With different elevation, the liquid phase will accumulate in the bottom of the pipe closing the pipe and in the respond of that, pressure build up. Comes the maximum pressure of the gas below the pipe, it will burst out all the slug and the process are repeated again and again.

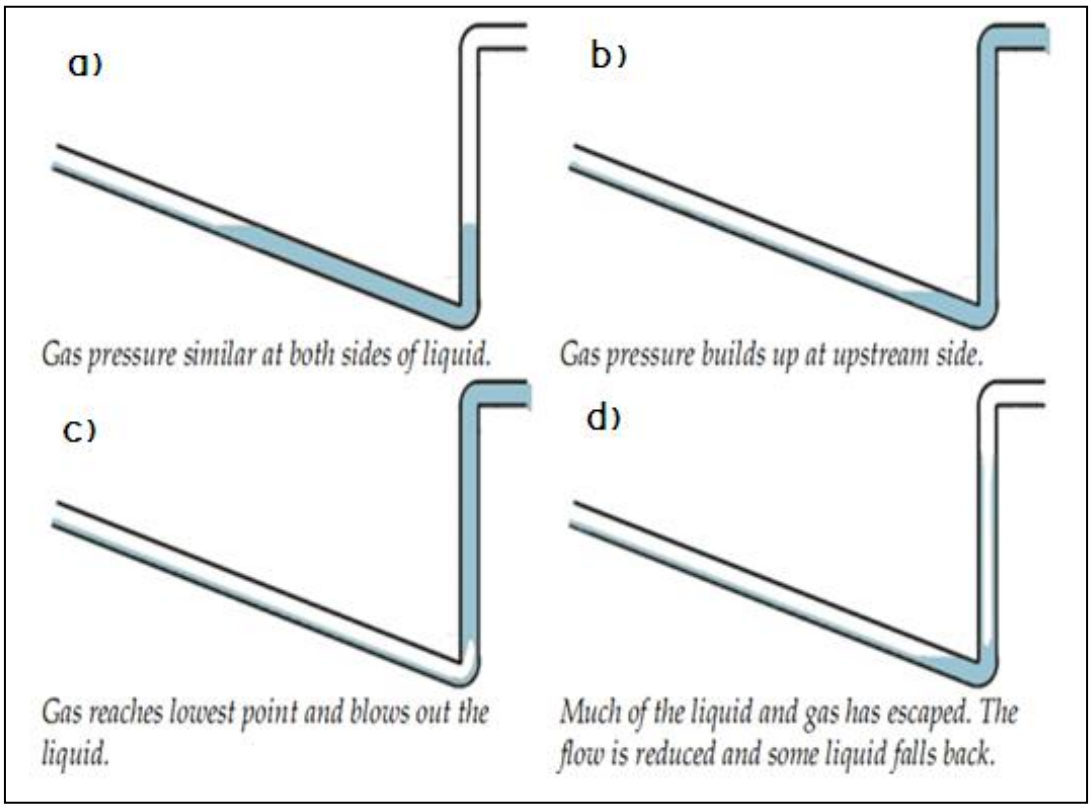

Figure 1.3: The terrain-induced slugging.

Source: (Devold, 2009)

Short pipeline distance are not a problem, but with longer distance pipeline, a multiphase flow can be created thus will form sever slug. Separation process and overpressure safety shutdown are the main effect from severe slugging. Furthermore, at high pressure pipeline, slug may freeze at normal sea temperature.

1.1.1 Main Process Section of Full Well Stream

The process will be described in detail in the following section. First the wellheads need to be discussed. The wellhead sits on top of the actual oil and gas well leading down to the reservoir. Various methods for wellhead such as injection well, which is used to inject water or gas back to the reservoir to maintain the reservoir pressure and level therefore maximize the oil production. Located in the subsea level, the wellhead must be design to endure high sea pressure and it need to be rigid for long cycle used time. (Mokhatab, 2006)

The raw crude oil coming from the wellhead or better known as full well stream (FWS) consist of many contaminants. This contaminant for example is H_2S, a acidic gas that can react with water to create acidic liquid. CO_2 can also react with water to become a corrosion problem. Need to be said that some sand and mud also travel with the FWS and this contaminants need to be removed before FWS can be used.

1.1.2 Crude Oil and Natural Gas

It a complex mixture which consist of 200 or more different organic compounds, which mostly alkenes and aromatic compound. Alkenes are single bond hydrocarbon on the form of C_nH_{2n+2} and smaller fraction aromatics such as the six-ring molecules such as benzene C_6H_6.

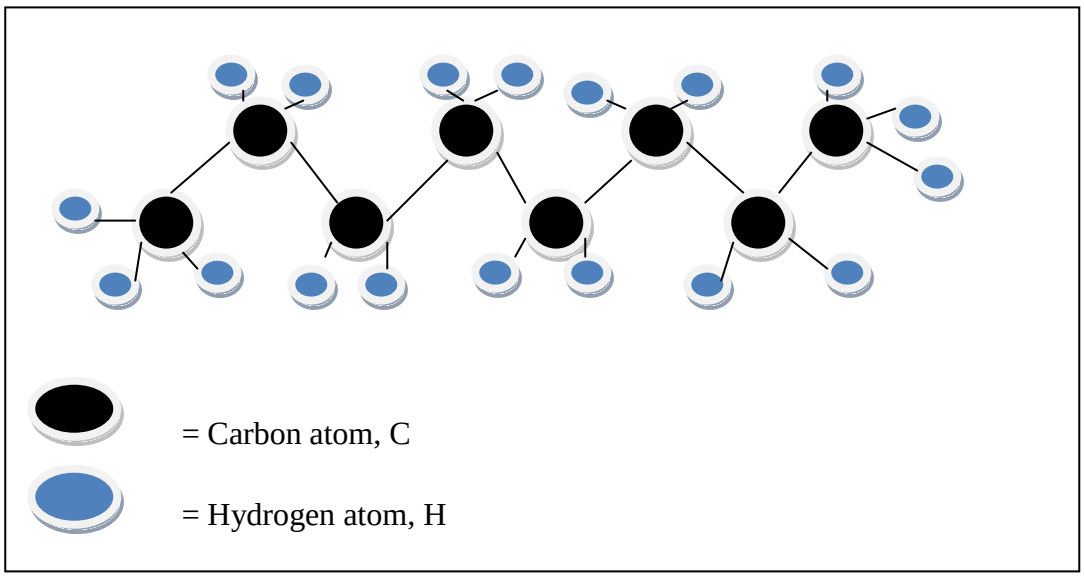

Figure1.4: Octane – C_8H_{18}

Crude oil can be very different or significantly similar in composition of compound even from a different field or even on the same reservoir field. Sulfur and other contaminant also are factors in characterizing crude oil grad as it needs to be removed.

Natural gas often flows with condensates. Condensates consist of ethane, propane, butane and pentane. This fluid often called as natural gas liquids or NGL. NGL are a very valuable by-product of natural gas processing and these are sold separately and can either

be used a raw material for various oil refineries or petrochemical plants or simply as a source of energy. (Devold, 2009)

1.2 PROBLEM STATEMENT

In the transportation of the natural gas, the liquid phase of natural gas will cause slugging in the pipeline. Slugging will cause damage to equipment in the gas terminal therefore there are need to use slug catcher. For this research, we focused on the finger-type slug catcher. So for the first problem for the finger type slug catcher is the long finger pipelines that are needed for large quantity of slug volume. This will consume many space in which can be used for others purpose.

Another problem is that inside the finger-type slug catcher, there are uneven mass flow of the natural gas between the gas and liquid phase. With uneven mass flow, the efficiency of separation will become low and thus we cannot get all the gas which is trap between the liquid phases of the flow.

1.3 OBJECTIVES

The objective of this research project is to maximize the potential efficiency of separation between gas and liquid phase using finger-type slug catcher by increasing the mass flow distribution inside the finger type slug catcher by more than 5%. By adding additional split at the inlet pipe, more gas can be separated inside the slug catcher due to the more efficient mass dispersion and this will decrease the slug flow and stabilize the flow itself.

1.4 SCOPE OF STUDY

In order to achieve the objectives, the following scopes have been identified. Such test and simulation is only using Gambit and Fluent to test the simulation outcome. It is not an experimenting procedure and only for simulation purpose. The process flow diagram is taken from the PFD at Onshore Gas Terminal Kertih. The raw natural gas type is the non-associated gas stream coming from offshore production into Gas Processing Plant. This stream only consists of natural gas and not the mixture of gas and crude oil. Treatment is only for water and heavy hydrocarbon removal disregarding the acid and H2S contamination. Malaysia's crude oil characteristic such its viscosity, surrounding area temperature and terrain condition.

1.5 RATIONALE AND SIGNIFICANCE OF THE RESEARCH

Natural gas carries many contaminant in which is hazardous if the natural gas is to be put into pipeline without proper treatment. For water, it can cause corrosion and maybe the formation of hydrate; it will clog the pipeline and damaged it. The cool temperature of the surrounding environment will cause the heavy hydrocarbon to turn into liquid phase. Hence the need to place pretreatment units (Slug Catcher) at the end of every pipeline from offshore before it enters the Gas Processing Plant. Fewer shutdown causes by slugging can be achieved if the flow into the separator is stabilized. But the most important thing is the enhanced of natural gas recovery from the flow. Thus this research has it significance in making natural gas production more efficient in cost effective and lesser time in production.

CHAPTER 2

LITERATURE REVIEW

2.1. SLUG IN LONG PIPELINE

Slug happen when two phase flow such as gas and liquid phase travel together in a pipeline. For such, gas travel much faster than liquid thus creating two different flows in a constant feed. With gas in higher pressure and velocity, the effect in the liquid phase is that it creates a wave which in time will accumulate and block the entire pipeline. When the pressure of the gas reached the maximum point, the gas will burst out causing all the liquid to flow out at all in the same time. There are many type of slugging for example. (Andreussi & Bendiksen, 2007)

2.1.1 Hydrodynamic Slugging

This slug happens in near horizontal part of the flow lone, but they are also common to happen in wells and risers. This type of slug is short and happens frequently. This slugging is not crucial and can be handled easily.

2.1.2 Elevation Slugging

Also known as severe slugging, an elevation slugging contains a lot of liquid/condensate and can cause major damage to downstream processing equipment. It happens in offshore oil production facilities. With liquid accumulate at the bottom of the riser, it builds up pressure and when maximum pressure are generated, the liquid will burst out and bring with its slug of liquid and gas form.

Slug can cause several damage or trip to equipment used in gas processing plant. One of the common causes of slugging is that slug cause severe problem to trip the high-high inlet separator level, and cause frequent and unnecessary shutdown of the equipment. The high momentum velocity of slug also causes wear and tear of equipment. The slug characteristics which are high pressure flow can cause high pressure trips and unnecessary flaring.

2.2. SEPARATION

Pure gas production that comes from some well can be directly taken to gas treatment or uses directly for compression. This is a rare situation where the reservoir give only pure sales gas and not a combination of others substance. Most reservoirs, the combination of gas, oil and water and various contaminants come together and in this case, the contaminants and the different phases need to be separated first. Hence the separation part of any oil and gas industry. (Mokhatab, 2006)

There are many method and design, but the classical methods that are used nowadays are gravity separator which uses the gravity separation method. The Full Well

Stream (FWS) is fed into either a horizontal or vertical vessel. Different vessel size and design give different residence time, but the general time is typically 5 minutes. The residence time is necessary as it allowed the gas to bubble out from the gas and the water to settle below leaving the oil to be extracted in the middle. The pressure is reduced in stages such as high pressure separator, medium pressure separator to low pressure separator depending on the FWS initial pressure. (Devold, 2009)

2.3. SLUG CATCHER

Slug catcher is by definition is a treatment to remove liquid particle and matter that flow with the raw natural gas. Slug as mentioned in section 2.1, will cause production to halt or damaged as the production equipment is not specifically design to handle liquid phase natural gas. The recommended method on removing slug is by using gravity conventional separators. This method use the phase density and residence time to separate different phase. As natural gas is less dense than heavy hydrocarbon, the natural gas will basically travel upward and being separated with water and heavy hydrocarbon which is much heavier in mass. (Carney, 1951)

From figure 2.1, the phases inside of the slug catcher is basically the same as a standard separator as it consist of three different phase. The gas phase occupied the upper side of the separator; the heavy hydrocarbon which is the oil occupied the middle space while the water which is the denser occupied the bottom part. The reason the principle of it working is the same because finger type slug catcher uses the method of gravity conventional separator.

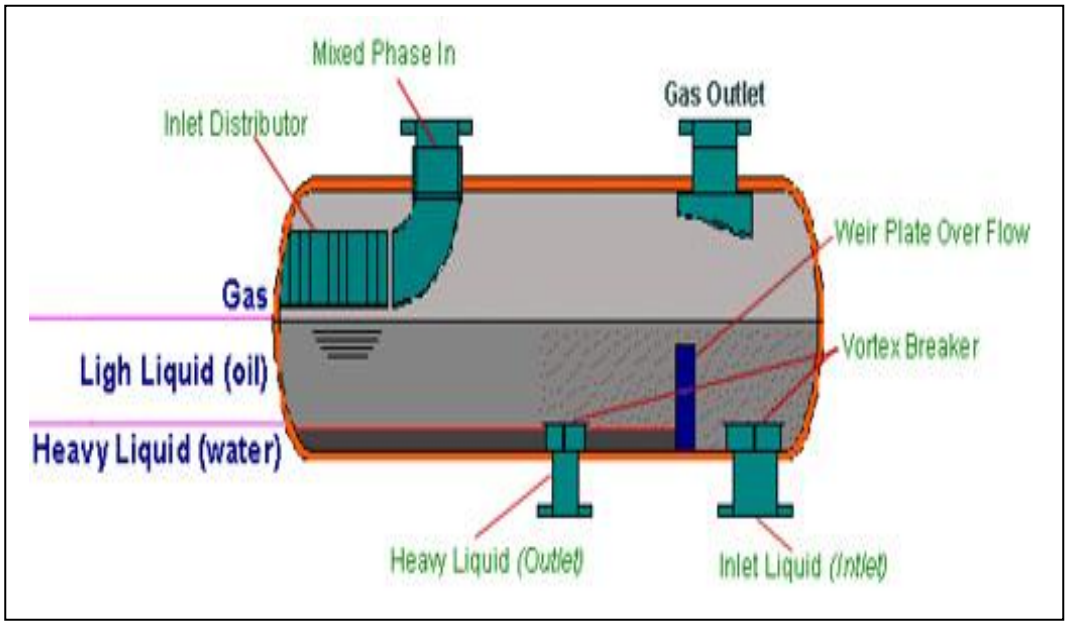

Figure 2.1 Slug Catcher

Source: (Devold, 2009)

2.4. SIZING FACTOR FOR FINGER TYPE SLUG CATCHER

Industry has very specific need in which must be cater in order to achieve its goals or target for production. Two common slug catchers usually used in industry which are the finger type and the vessel type slug catcher. (Devold, 2009)

The purpose of slug catcher as mention in section 2.2 is to trap or separate slug and water from natural gas. Finger type slug catcher can support medium volume for liquid but vessel type slug catcher can support larger quantity of liquid volume than the finger-type.

This is due to its design capacity. The upside of it is that finger type slug catcher has more efficiency than the vessel type slug catcher in separating slug than the vessel type. The downside of this is that finger-type slug catcher is often long and big to be installed in offshore production where clearly space is limited. Such statement is proved by this research.

The “multiple-pipe” slug catchers (“Finger Type”) equipment is the most common equipment to handle slug volume, it is efficient and the operation is well known, however the common practice recommends that for volumes less than 100 m3. For volumes less than 100 m3, it is better to use the “vessel type” (this would be our case with 26, 35 m3.) According to the rule of thumb the selection should be “Vessel Type”, where 18 MMsm3/d is considered the gas flow for the design, that results in a diameter of 102 inches by 14 meters long and a weight of 150 tons for the equipment size. (Marquez, Manzanilla, & Trujillo, 2009)

2.4.1. Finger Type Slug Catcher

Finger type slug catcher consists of many long pipe pieces in which are interconnected with each other. It will usually have three stage will separate the different phase of the natural gas which is natural gas, liquid phase hydrocarbon and water. Gas terminal often use this slug catcher because of it is simpler design which is suitable for high pressure which is common in pipeline system. The downside of it, finger-type slug catcher is simply large as this figure show.

Figure 2.2: Finger-type slug catchers at Den Helder, The Netherlands.

Source: (Devold, 2009)

See the long pipeline for the finger-type slug catcher. This is an example of a large finger-type slug catcher at Den Helder, The Netherlands. The existing pretreatment units for handling slug and water vapor depend on the condition of the stream that coming to the Gas Processing Plant itself. Vessel type or Finger type slug catcher are the usual selection in pretreatment unit. Each of the unit has its own distinction of advantages and disadvantages. For the vessel type slug catcher, it is suitable in handling large quantity of liquid going up to 1000 to 3000 m3. It is cheaper in installation cost but cannot say the same for the work delivery and the transportation cost.