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Advanced Optimization of Natural Gas Recovery Utilizing Twister Supersonic Gas-Liquid Separation Technology

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Abstract
The optimization of natural gas recovery is indispensable for minimizing operational costs in the gas value chain. Natural gas is one of the most precious natural resources that generates foreign earnings to its host nation. The production and subsequent recovery of natural gas is a challenging aspect of the entire natural gas processing. Gas-Liquid Separation is one problem with natural gas utilization, as the gas is extracted with certain percentages of water and other contaminates. Conventional separation methods deployed to handle this problem often face limitations in the treatment of complex gas-liquid mixtures, mainly in high-pressure and high-flow environments. This paper presents the use of the Twister Supersonic Gas-Liquid Separator, a cutting-edge technology that leverages supersonic flow dynamics and centrifugal forces to achieve superior separation efficiency. By swiftly cooling and separating gas from liquids and condensates, minimizes hydrate formation risks and mitigates flow assurance issues, enabling higher recovery rates and improved process stability. This study demonstrates how the Twister system can outperform traditional methods in terms of recovery efficiency. Numerical simulations [Aspen Hysys] and case studies [Notore Chemical Industries] are used to highlight the system's effectiveness for optimizing gas processing operations. Notore Chemical Industries is one of the largest natural gas consumers, situated in Rivers State Nigeria. The company has several plant downtimes due to the inefficiency of the conventional separator. The inefficiency of the installed knock out drum separator to disperse the condensate from the feed supplied from Nigerian Gas Company (NGC) and deliver the required dry gas to the plant battery limit has been one of the leading causes of the plant recording downtime. This paper presents a reliable separation process using the Twister supersonic gas separator to recover high percentage of dry natural gas (Methane). Feed gas data from the plant was used and a simulation was conducted. Result indicates that Twister supersonic gas separator is more efficient than the knockout drum separator. Less methane and less condensate was produced using knockout drum separator at 0.699% and 0.092% respectively while the Twister supersonic gas separator produced methane and condensate at 95.15% and less condensate 0.0047% respectively. The results presented offer a novel approach to gas-liquid separation that can significantly support sustainable development in natural gas utilization.

Key Word: Natural Gas Recovery, Supersonic Gas-Liquid Separator.

1. Introduction
Natural gas recovery is critical for enhancing efficiency and minimizing operational costs in the gas value chain. Hydrocarbon recovery using the Twister technology is research that is designed to solve Notore Chemical Industries technical problem within the plant battery limit. The study presents a new separator to deliver natural gas without wastage or without liquid carryover to the primary reformer unit of the facility. A comparative study of the existing separator and the proposed separator which is twister supersonic was presented. The entire study was conducted using a powerful simulation tool. Both separators volume of dry

gas delivery was recorded. The volume of gas wastage and the number of times the plant has been shut down as a result of inefficiency knock out separator has led to process engineers to seek for alternative. Many gas and oil industries with the task of delivering dry gas to national power grid and petrochemical facilities over time encounter this similar problem. In fact, costly equipment in Notore Chemical Industries plant such the primary reformer process unit which consist of tubes and catalyst, high pressure steam flow-lines, reinforced steel materials, secondary reformer, heat exchangers, compressors, gas turbines and the entire plant rely on the good performance of the natural gas knockout drum. The inefficient gas-liquid separation in many end user plants has caused several problems leading to frequent plant down time. The objective of this research paper is to apply a new technology (Twister technology) that will improve the efficiency of the dryness factor of the natural gas streams. The result of each gas stream dryness factor was compared; gas dryness factor and condensate recovery per flow rate was considered and used. ASPEN Hysys software is used to simulate the existing separator and the twister supersonic separator and compare the level of Liquid carryover. Liquid carry over and Gas blow-by are one of the major industrial problem in Notore Chemical Plant knockout drum.

Natural gas is a vital energy resource and playing a key role in the global transition toward sustainable energy systems. Efficient recovery of natural gas, however, remain a challenge, especially in gas-liquid separation processes. An advanced technologies emerging to tackle this challenge is the Twister Supersonic Gas-Liquid Separator. Utilizing high-velocity gas dynamics and centrifugal forces, the Twister system achieves efficient separation of gas and liquids under supersonic conditions, eliminating the need for conventional phase separators and demisters. This paper aims to explore the optimization of natural gas recovery through the Twister Supersonic Gas-Liquid Separator. Investigating the principles of supersonic separation, provides insights into achieving maximum gas recovery rates and operational efficiency. The discoveries of this paper can Notore and guide field operators in selecting the most effective separation techniques, finally enhancing the economic and environmental sustainability.

Natural gas supply containing high percentages of heavy hydrocarbon (Condensate) and Water instead of high percentage Methane from Nigerian Gas Company to Notore Plant for utilization. Based on the raw gas data collected, this volume of liquid recorded in the gas stream from the downstream is one of the major problems Notore is facing as a downstream gas utilization company. This problem has led to several plants downtime and shortages in productivity. The Industrial complex of the chemical process plant is strategically located at Onne, 4 kilometer away from the state capital Port Harcourt, Rivers State, Nigeria. This company receives huge volume of natural gas supply for daily utilization. With a daily gas consumption capacity of 47mmscf, the facility stands out as one of the natural gas consuming process plant in Nigeria. The plant was owned by the former National Fertilizer Company of Nigeria (NAFCO) before it was acquired by Notore. This gas utilization facility owns a jetty (by the Atlantic Ocean) for easy export of the final products which Urea chips and ammonia. It also serves as import line of other of raw materials and export of products. This processing plant has the capacity of 50 Megawatts of power generation from two different 25megawatts gas turbines. One of the 25 Megawatts power plants is currently under rehabilitation. The company also signed a 20 year gas contract at a very low price in June 2006 (effective from 2009). The gas contract will lead to the supply of sufficient gas to feed current plant and planned expansion i.e. Trains I & II Notore enjoys a significant price premium in the local market versus imports. Own the only producing urea fertilizer plant in the whole of Sub-Saharan Africa; annual production capacity is 500,000 metric tons of Urea and 600,000 metric tons of blended NPK Asset located in Nigeria, a large and growing market for fertilizer; domestic consumption in Nigeria is currently estimated to be between 1.200,000 – 1,700,000 metric tons per year, Own Nigeria's Largest Fertilizer Marketing, Sales and Agricultural Services team as well as an effective. notore.com

2. Review of Literature

Natural Gas

Natural Gas is a mixture of hydrocarbon gases along with some impurities. Consist primarily of saturated light alkanes such as methane and ethane while propane, butane, pentane, and hexane may also exist in natural gas. Hydrocarbons occur in most part in gaseous form in the reservoir because of high pressure, they liquefy at the surface and as produced natural gas liquids (NGLS), and it can be presented as gas cap above the crude oil in a reservoir associated or wet gas. The gases in natural gas Nitrogen, Carbon Dioxide, Hydrogen, Helium and Argon also Nitrogen and Carbon Dioxide are noncombustible and may be found in substantial proportions and may reduce the heating value of natural gas www.britannica.com. The rich gas is transported to processing plants where the dry gas and wet gas (the associated hydrocarbons) are separated. The wet gas is then heated in order to separate the different components, which in turn is sold in component markets (Waddams et al., 2024).

The prospects for the development of natural gas include the following: It is a possible substitute in the transport sector either in the form of Compress Natural Gas (CNG), Liquefied Natural Gas (LNG), Liquefied Petroleum Gas (LPG) or in the form of a derivative of natural gas liquids e.g. methanol. It is a possible fuel substitute for electricity generation or industrial use. It is therefore very pleasing that the Nigerian Government has taken a bold step — the setting up of the Nigerian Gas company that sale natural gas to Notore Chemical Industry, the Liquefied Natural Gas Company and petrochemicals company all subsidiaries of the Nigerian Natural Petroleum Cooperation towards the proper and efficient utilization of its abundant gas reserves (Alexander et al., 2023). The aim is to evaluate the performance of Notore's plant feed gas knockout drum for gas condensate recovery. Use a software to run simulation and compare with recent technology (Twister Separator) record both results and recommend a better option for Notore's management. To meet the company's annual production capacity of 500,000 metric tons of Urea and 600,000 metric tons of blended NPK Asset located in Nigeria. With a large and growing market for fertilizer; domestic consumption in Nigeria is currently estimated to be between 1.200,000-1,700,000 metric tons per year, https://notore.com.

Separators

Separators are installed at the head of the processing chain, in which they are the essential elements. They receive, directly from the inlet manifold, the production brought from the collecting pipes. A separator is a capacity under pressure incorporated into a circuit, in which it slows the flow velocity of the effluent. A separator is a cylinder positioned either vertically or horizontally. There are also spherical separators, but they are not used so commonly. Branch connections with valves and measuring devices are used to control the operation. According to the specific use, separators can be classified into: Flash separators used for condensate gas processing. Gas/Liquid separators, Gas/oil separators, free water separators, Test separators, Scrubbers (e.g. a flare drum) and filters. The different types will be described below Ahmed et al (2020). There are many types of separators for the process industry. Basically, there are three types, namely; Vertical Separator Horizontal Separator Single Tube Horizontal Separator Double Tube Horizontal Separator Spherical, (Caldentey 2000).

Gas Liquid Separators

Gas liquid Separation is a critical field processing operation. As producing pressure is increased and lighter condensates are produced, efficient separation has become more critical than ever. Moreover, some of the new concepts in separation technology have been applied to advantage on old lease producing gas at moderate or low pressures, Brown, (1994). As gas transmission lines and end users raise their standards. Separation becomes a part of the overall field processing necessary to condition the gas. Several technologies are available to remove liquids and solids from gases. Selection should be made based on the droplet size, concentration, and whether the liquid has waxing or fouling tendencies.

Gravity and Vertical Separators

Gravity separators are pressure vessels that separate a mixed-phase stream into gas and liquid phases that are relatively free of each other. In a gravity separator, gravitational forces control separation. The efficiency of the gas/liquid separation is increased by lowering the gas velocity. Because of the large vessel size required to achieve settling, gravity separators are rarely designed to remove droplets smaller than 250m. However, an analysis of this type of separator is given because it is useful to help understand the settling mechanism of other separators. Gravity separators are often classified by their geometrical configuration (vertical, horizontal) and by their function (two-phase/three-phase separator) Brown, (1994).

These separators are used in the following conditions. Small flow rates of gas and/or liquids. Very high GOR streams or when the total gas volumes are low. Plot space is limited. Ease of level control is desired. Advantages and disadvantages of these separators are as follow. The following are the advantages of a vertical separator: Liquid level control is not so critical. Have good bottom-drain and clean-out facilities, can handle more sand, mud, paraffin, and wax without plugging. Occupies smaller plot area and less tendency for re entrainment (Wang et al., 2003).

Knockout Drum Separator

A Knockout drum is a type of vapor–liquid separator, a device used in several industrial applications to separate a vapor–liquid mixture. For the common variety, gravity is utilized in a vertical vessel to cause the liquid to settle to the bottom of the vessel, where it is withdrawn. There are categories: free water and total liquid knockouts. The free water knockout is a vessel used to separate free water from a flow stream of gas, oil, and water. The gas and oil usually leave the vessel through the same outlet to be processed by other equipment. The water is removed for. The total liquid knockout is normally used to remove the combined liquids from a gas stream disposal. Separator (exheat.com) - In low gravity environments such as a space station, a common liquid separator will not function because gravity is not usable as a separation mechanism (Stanley, 2004).

Slug Catchers

Slug catchers are used basically at the terminus of offshore pipelines to catch large slugs of liquid in pipelines, to hold these slugs temporarily, and then to allow them to follow into downstream equipment and facilities at a rate at which the liquid can be handled properly. In Notore there is a Slug catchers installed within the filters to enable the natural gas movement to the separator expander. Slug catchers may be either a vessel or constructed of pipes. Pipe-type slug catchers are frequently less expensive than vessel type slug catchers of the same capacity due to thinner wall requirements of smaller pipe diameter (Gomez et al., 2000).

Removal of Water Vapour

For the removal of water vapor from natural which is dehydration process, Ikoku, (1992), proposed the used of four methods-direct cooling, compression followed cooling, absorption and adsorption. The first two methods do not result in sufficient low prevent injection into pipeline, hence are not commonly used. Absorption and adsorption are accomplished by the use of liquid desiccants glycol dehydration and solid desiccant dehydration respectively. Solid desiccants commonly used include silica, alumina and certain silicates known as molecular sieves. These have the advantage of producing essentially dry gas (moisture content less than 1.0b/MMCF) low dew points are obtained over a wide range of operating conditions and high contact temperature can be tolerated with some adsorbents (Arnold & Stewart, 1998).

Condensate

Hydrocarbon condensate recovered from natural gas may be drained without further processing but is stabilized often for blending into the crude oil stream and thereby sold as crude oil. In the case of raw condensate, there are no particular specifications for the product other than the process requirements. The process of increasing the amount of intermediates (C3 to C5) and heavy (C+ 6) components in the condensate is called “condensate stabilization.” This process is performed primarily in order to reduce the vapor pressure of the condensate liquids so that a vapor phase is not produced upon flashing the liquid to atmospheric storage tanks, (Iyagba, 2013).

Twister Supersonic Separator

The Twister supersonic separator is a unique combination of known physical processes, combining expansion, cyclonic gas/liquid separation, and recompression process steps in a compact, tubular device to condense and separate water and heavy hydrocarbons from natural gas. Condensation and separation at supersonic velocity is the key to achieving step-change reductions in both capital and operating costs https://www.twisterbv.com/twister-supersonic/. The residence time inside the Twister supersonic separator is only milliseconds, allowing hydrates no time to form and avoiding the requirement for hydrate inhibition chemicals. Elimination of the associated chemical regeneration systems avoids harmful benzene, toluene, and xylene emissions to the environment or the expense of chemical recovery systems. The simplicity and reliability of a static device, with no rotating parts, which operates without chemicals, ensure a simple facility with a high availability suitable for unmanned operation in harsh and/or offshore environments, (Brouwer et al., 2004).

Gas Dehydration Twister Process Description

Feed gas is pre-cooled against the cold treated gas in a Gas-Gas Heat Exchanger (GGHEX). An additional parallel or in-series Gas-Liquid Heat Exchanger (GLHEX) can also be used to provide further pre-cooling. The temperature at the end of the pre-cooling is maintained above the hydrate formation temperature (HFT) if a chemical free operation is desired. The liquid formed in the pre-cooling process is removed in a gas-liquid separator usually referred to as the Inlet Separator (IS). The gas then enters the Twister tube(s), which expand(s) the gas to a supersonic velocity, using static turning vanes to bring the gas into a swirling motion. The expansion causes a rapid drop in temperature, which results in an instant formation of microscopic droplets consisting of heavier hydrocarbons and water. The centrifugal forces are typically 500,000g, sufficient to force the microscopic droplets to the wall. A simple pipe-in-pipe configuration separates the dry gas core from the liquid. The two separate product streams are then recompressed in a diffuser section, reducing the velocity and thereby recovering most of the pressure. The liquid separated by Twister tube(s) still contains some slip-gas, typically 30-35% of the total gas stream, which is then removed in the downstream liquid de-gassing vessel and recombined with the primary gas stream. The temperature reached inside the Twister tube(s) is well below the hydrate formation temperature www.twisterbv.com.

Notore's Problem of Entrainment/Carryover

Entrainment/carryover of liquid has been serious process problem in Notore's Plant and this phenomenon associated with systems in which the liquid and gases or vapors are in relative motion owning to much condensate received from the Nigerian Gas company. It may be defined as pneumatic conveyance of drops of liquid into gaseous phase. It has been extensively observed in number of process equipments where phase separation takes place due to gravity such as industrial boilers, evaporators, distillation columns and also in Nuclear reactors. In a bubbling pool, when the vapour bubble leaves the free surface, the bursting of bubble or/and jetting of vapor leads to formation of liquid droplets. The liquid droplets carried along by gas(carryover) may cause mechanical damage to process equipments due to dissolved salts carried by liquid droplets along the steam, reduction in separation efficiency in evaporation, distillation or absorption columns, severe damage in turbines and transport of volatile radio-nuclides in case of steam generators for nuclear reactors. Carryover depends on various factors such as size and velocity of droplets, bulk velocity and flow pattern of the vapour phase, nature of forces on the droplet moving relative to vapour phase, fluid properties, viz., surface tension, viscosity, density, bubble dynamics at and below the separation interface, etc. Carryover effects can be reduced by using extra equipments like steam washers, steam dryers and mist separators.

3. Methodology

The step by step approach adopted in carrying out this research paper and to realize the objectives, the following procedures were adopted. Several visit to Notore Chemical Plant for data collection and other relevant information towards the work. The data collected were plant input/output operational parameters as well as manufacture's design parameter which includes the plant knock out drum operational conditions, such as the pressure, temperature, and flow-rate. The manufactures design data were compare with the recent plant operating conditions in order to evaluate the performance of the knock drum, and result were collected and noted. Aspen Hysys software was used to simulation the existing separator and results were obtained which was used to also compare a recent separator technology. In order to achieve the designed capacity of the separator, detailed information about the plant design natural gas specification and the gas turbine natural gas design specification which is to utilize 17mmscf daily for 50mw power generation from two installed gas turbine. The reference natural gas processing equipment use for this thesis work was the Notore Chemical Industries' Plant Feed Gas Knockout Drum 2106-F in Onne, Rivers State, Nigeria. The gas sample before the entrance of Notore chemical industries was collected and analyzed using the gas chromatography for its constituents. The gas stream is then analyzed again of its constituents after the knock out drum and dew point analyzer was also used to know the temperature at which the natural gas fraction will condense for proper separation. The gas sample before the entrance of Notore chemical industries was collected and analyzed using the gas chromatography for its constituents; the gas stream is then analyzed again of its constituents after the knock out drum. Then Aspen Hysys was used to run a simulation to determine performance and properties, and help recommend a better option for the management. The inclusion of the twister technology using computer aided Engineering (CAE) packages (Aspen Hysys) on the gas stream prior to the plant under the same operating conditions. An analysis of the outlet stream of the Twister technology for its comparative study of the three gas streams in terms of efficiency was done. The design and operating condition data was collected from Notore Chemical Industries and presented for detailed information about this work. Graphs were plotted to show the relationship between the existing plant knockout drum performance and the Twister Supersonic Separator.

Notore's Process Description

Notore Chemical Industries feed Natural gas is received at the plant complex battery limits at a pressure of 45.8kg.cm^{2}g. The natural gas supplied to the plant complex is metered by flow element FE-511(Daniel Orifice Meter). The imported natural gas filtered by natural gas filter, 2018-L or 2018-LA, to remove any rust for scale particles that may be carried through the gas pipeline. The filtered natural gas is directed to the fuel gas knockout drum, 2106-F, on pressure control. Any hydrocarbon condensate removed from the gas in the knockout drum is distributed to the natural gas from the knockout drum to distribute to the ammonia plant for use as feedstock and fuel gas. The natural gas is supplied to the ammonia plant battery limits at a pressure of approximately 43.7kg.cm^{2}g and to the natural gas letdown station for use as fuel gas in the NPK unit, the product bagging area shrink tunnels, the burn pit flame front generator and the burn pit pilot burner at a pressure of approximately 8.0 kg.cm^{2}g, Natural gas from the knockout drum is also directed through the fuel gas heater, 2001-c, to the low pressure fuel gas knockout drum, 2111-f. the natural gas pressure is reduce to approximately 20.3 kg.cm2g before entering the low pressure fuel gas knockout drum. Any condensate remove from the low pressure fuel gas is manually drained to the burn pit for disposal. Natural gas from the low pressure knockout drum is used for the fuel gas in gas turbine generators, 2006-J and 2006jA, the supplemental burner and pilot of the waste heat boiler, 2006-U, and the main burner and pilot of the package boiler, 2007-U. The fuel gas to the turbine generators can be warmed by the gas turbine start-up heater, 2002-CA, before going to the turbines duel gas pressure control systems. The natural gas pressure is reduced to approximately 7.0kg/cm2g before being directed to the waste heat and package boiler fuel gas pressure control system. Fuel gas from the low pressure knockout drum is also supplied to the main laboratory, the training facility and the canteen building. The fuel gas pressure to these users is also reduced to approximately 7, 0 kg /cm2g before being directed to user pressure regulators. In reviewing this system, refer to the following drawings for clarification (Notore Process Plant Manual, 2014).

Description of flow and Equipment

The Fuel gas system consists of the following major equipment. Natural Gas Filter: 2018-L/LA Type: pipeline filter with cleanable and reusable elements service: To remove dirt, rust and pipeline scale operating pressure: 45.8 kg/cm2g. Design pressure: 70.0 kg/cm2g. Operating Temperature: Ambient. Design Flow Rate: 56, 311 kg/hr each. Normal Flow Rate: 42, 443 kg/hr each. Maximum Allowable pressure Differential: 0.35 kg/cm2g

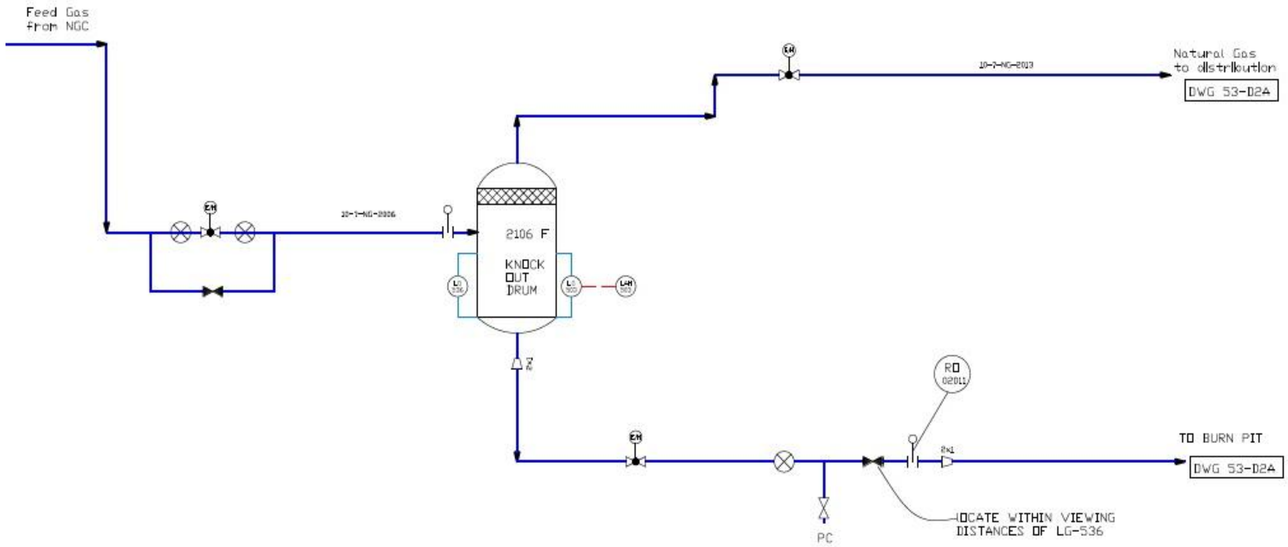


Fig 3.1 Fuel Gas Knockout Drum 2106 –F

Each of the unit operations are properly defined, the operating parameters based on design data collected from the plant battery limit. These data were used to perform the simulation and input parameters includes Fuel Gas Knockout Drum 2106 –F; Type: Vertical drum mist eliminator. Operating pressure: 43.7 kg/cm2 g. Design pressure: 51.0 kg/cm2 g. Design Flow Rate: 56. 311 kg/hr. Normal Operating Flow Rate: 42, 433 kg/hr. Fuel Gas Heater 2001 – C; Type: Finned tube and shell. Shell side: Natural gas. Tube side: Low pressure steam. Design Flow: shell side -15, 985 kg/hr. Tube side – 178 kg/hr. Low Pressure Fuel Gas Knockout Drum 2111 –F; Type: vertical drum with mist eliminator. Operating pressure: 2 0. 3 kg/cm2 g. Design pressure: 23. 3 kg / cm2 g. Design Flow Rate: 15,985 kg/hr. Normal Operating Flow Rate: 10, 840 kg/hr. Normal Operating Flow Rate: 10, 840 kg/hr. Star – UP Gas Turbine Heater 2002 – C; Type: Electric-450 volt 3 Phase 50 Hz. Fuel gas inlet pressure: 20, 3 kg /cm2 g. Normal Operating Fuel Gas Flow Rate: 5840 kg/hr. Burn Pit 2406 –A. Designed to Fire: 1.0 $_{m}$3/hr of condensate (natural gasoline) in combination with 55NM3 /hr of natural gas. Heat Release: Maximum-2,520, 000 kcal /hr. Minimum- 840, 000 kcal / hr. Normal -2, 080,000 kcal / hr; Components: Burn pit burner 2401 – B2. Natural gas is used in the plant complex as feed gas for the ammonia production process and as fuel gas. The natural gas will be supplied to the plant complex by pipeline from the Nigerian National Petroleum Corporation. The natural gas is received and metered at the plant complex battery limited by FE – 511 through line NG -2001 -10". The natural gas import flow rate is recorded in the offsite control room on FR – 511 and FR -511A. in normal operation of the plant complex, the Normal flow of natural gas will be approximately 42, 443 kg / hr at 45.8 kg /cm2g pressure. The maximum design flow rate flow is 56,311 kg/ hr. The natural gas is filtered by filters, 2010 – L and 2018 –LA, before being directed to the fuel gas knockout drum, 2106 –F. The natural gas pressure is reduced from 45.8 kg/cm2g to 43.7 kg/cm2g before entering the knockout drum. The pressure of the natural gas is controlled by the local pressure regulator PVC – 516. Any Liquid condensed in the fuel gas knockout drum must be manually drained to the burn pit, 2406-A, for the natural gas flow from the fuel gas knockout drum is metered by FE – 501 and recorded and tantalized in the offsite control room on FR -501. The natural gas pressure, density, temperature recorded, TR-507, and calorimeter recorder, AR-517, located in the off sites control room. The natural gas high pressure distribution systems is protected from over pressure by the safety relief values, RV-NG2013-1", RV-NG2013" and RV-NG2013-2" and RV-NG2013-3". The natural gas from the knockout drum is distributed to the ammonia plant for use as feedstock and fuel gas through lines NG-2013-10" and NG-2013-8". The normal flow will be approximately 31,030 kg/hr with a maximum design flow rate of 39,563kg/hr. the natural gas flow through line NG-2012-2" is used for fuel gas in the NPK unit, the product bagging and area shrink tunnel heaters, the burn pit pilot burner and the flam front generator. The natural gas let down station and restriction orifice located upstream of the knockout pot reduces the pressure to these users to 8.0kg/cm2g. Condensate collected in the knockout pot is manually drained to the burn pit for disposal. This section of the natural gas distribution system is protected from over pressure by the safety relief value RV-NG-2012. The natural gas flow through line NG-2010-4" is directed through the fuel gas heater, 2001-C, and the low-pressure knockout drum, 2111-F. this is used as fuel gas for the utility unity in various plant area such as the gas turbine generators, 2006-J and 2006-JA, the waste heat boiler, 2006-U, the package boiler, 2007-U, and in the main laboratory, training building and canteen. Low pressure steam is used to warm the natural gas in the fuel gas heater. The temperature of the fuel gas is controlled by temperature valve, TV-550, on signal from temperature indicator controller, TIC-550. The fuel gas temperature is also indicated on local TI-550. The pressure of the fuel gas entering the low-pressure knockout drum is reduced from 43.7kg/cm2 to 3o.3 kg/cm2g kgcm^{2}g by the fuel has heater.

Operating Problem

This paper is done to solve Notore's feed gas knockout drum by simulating it using Aspen Hysys software and also carry out a study on the working principle of Twister Supersonic separator technology, studies evaluating the performance of Twister against the knockout drum in order to recover NGL and have better dry gas for the plant gas turbine and for ammonia production. Figure 1.1 below is the analysis of the natural gas in the right proportion of methane with the Mole percentage of 93.14.

Table 3.1.- Natural Gas analysis.

						Heat of Combustion of Hydrocarbon at 25				Calorific Value of Natural Gas			
						NCV(low)	GCV(high)	NCV	GCV	NCV	GCV	NCV	GCV
Units /Gas Component	Mol. %	Mol. Wt	Kg	C #	C.Mol	Kcal/Mol	Kcal/Mol	Kcal/NM3	Kcal/NM3	Kcal/Mol	Kcal/Mol	Kcal/NM3	Kcal/NM3
CH4	93.14	16	14.9024	1	93.14	191.759	212.798	8.555	9.494	178.6043	198.2001	7.968127	8.842712
C2H6	2.95	30	0.885	2	5.9	341.261	372.82	15.235	16.633	10.0672	10.99819	0.449433	0.490674
C3H8	1.85	44	0.814	3	5.55	488.527	530.605	21.796	23.673	9.03775	9.816193	0.403226	0.437951
i-C4H10	0.43	58	0.2494	4	1.72	607.679	649.757	27.112	28.989	2.61302	2.793955	0.116582	0.124653
n-C4H10	0.57	58	0.3306	4	2.28	635.384	687.982	28.348	30.694	3.621689	3.921497	0.161584	0.174956
i-C5H12	0.11	72	0.0792	5	0.55	782.04	845.16	34.891	37.707	0.860244	0.929676	0.03838	0.041478
n-C5H12	0.07	72	0.0504	5	0.35	782.04	845.16	34.891	37.707	0.547428	0.591612	0.024424	0.026395
i-C6H14	0.03	86	0.0258	6	0.18	1002.57	928.93	44.73	41.444	0.300771	0.278679	0.013419	0.012433
n-C6H14	0.01	86	0.0086	6	0.06	1002.57	928.93	44.73	41.444	0.100257	0.092893	0.004473	0.004144
n-C7H16	0	100	0	7	0	1160.01	1075.85	51.754	47.999	0	0	0	0
N2	0.62	28	0.1736	0	0	0				0	0	0	0
CO2	0.22	44	0.0968	1	0.22	0				0	0	0	0
Totals	100	694	17.6158	44	109.95					205.7527	227.6228	9.179647	10.15539
Molecular Wt of NGC		17.6158	Heat Content of NGC(BTU/ft3			259.9676							
H2S	<5ppm												
NATURAL GAS ANALYSIS												NGC Heat Content	
N2	CO2	CH4	C2H6	C3H8	IC4	N-C4	i-C5	n-C5	i-C6	n-C6	H2S	BTU/ft3	NCV
0.62	0.22	93.14	2.95	1.85	0.43	0.57	0.11	0.07	0.03	0.01	<5ppm	259.9676	9179.647

Natural gas is supplied to the plant battery limits at a maximum design flow rate of 56,311kg/hr. The flow is indicated and recorded by FR-511 and FR-511A. The incoming natural gas is filtered by the natural gas filter, 2018-L or 2018-LA, to remove small amounts of dirt, rust and pipe scale from the gas. The maximum allowable pressure differential across the filter is 0.35kg/cm2g. The in-service filter pressure differential indicator switch, PDISH-562, which also activates the high differential pressure alarm, PDISH-562. When a high drop across the filter is indicated, the spare filter must be placed in-service and the in-service filter isolated and de-pressured. The dirty filter element can be removed and cleaned by using hot water and any non-volatile cleaning agent. The element should be completely dry before being returned for service. If the filter element is installed wet, a high initial pressure loss and premature fouling will occur. The filtered gas is directed to the fuel knockout drum, 2106-F, on pressure control. The fuel gas knockout drum pressure is controlled by pressure regulatory, PCV -516, and pressure control value, PV – 515, on signal from pressure indicator, PIC – 515. The knockout drum and fuel gas header pressure is indicted by local pressure indicators, PI – 518, and recorded in the offsets control room on PR – 517. In the event of a high or low pressure in the fuel gas system, pressure alarm, PAH – 517 or PAL – 517, will be activated in the offsets control room. The flow, density, temperature and calorific value of the fuel gas from the knockout drum is also indicated and recorded in the offsets control room.

If any liquid hydrocarbons are collected in the knockout drum, the liquid must be manually drained to the burn pit. The level of liquid in the knockout drum will be indicated by the local level gauge, LG – 536. In the event of a high liquid level in the knockout drum, the high level alarm, LAH-503, will be activated in the offsite control room. The flow rate of liquid hydrocarbon drained from the gas filter and knockout drum to the burn pit is limited by the drain lines restrictive orifice size. The nitrogen flow used to purge the hydrocarbon drain lines is also regulated by a restrictive orifice. The restrictive orifice is provided in the drain and purge lines to prevent slugs of hydrocarbon liquid from entering the burn pit. The burn pit burner pilot, 2401-B1, is fired by the flame front generator, 2401-B2. The flame front generator is located a safe distance from the burn pit. The operator of the burn pit is intermittent. Natural gas from the fuel gas knockout drum is supplied to the ammonia plant battery limit for use as feedstock and fuel gas at a pressure of 43.7kg/cm^{2}g. The natural gas pressure from the fuel gas knockout drum is reduced to 20.3 kg.cm^3 g by pressure let down station before entering the low pressure knockout drum. 211-F, located in the utility area, the low pressure knockout drum, 211-F, located in the utility area. The low pressure knockout drum pressure is controlled by pressure regulator, PCV-564, and pressure control valve, PV-560, on signal from PIC-560. The fuel gas supplied to the low pressure knockout drum is warmed by heat exchange with low pressure steam in the fuel gas heater, 2001-C.

Temperature valve, TV-550, controls the fuel gas temperature by regulating the steam flow to the fuel gas heater on signal from the temperature indictor controller, TIC-550. The fuel gas must be heated approximately 30^{o}C above the gas dew point to prevent condensation of liquid hydrocarbons when the pressure is reduced. Liquid fuel entering the gas turbines combustion chambers or boiler burners could cause unstable operation and possible damage to the equipment. Any condensate collected in the low pressure fuel gas knockout drum should be drained to burn pit. The knockout drum level can be observed on the local level gauge, LG-566. In the event of a high level in the knockout drum, the high level alarm, LAH-565, will be activated in the offsite control room. If any liquid level is observed in the knockout drum, the fuel gas temperature should be increased. The low pressure fuel gas knockout drum pressure is indicated on local PI-561 and fuel gas temperature is indicated on local TI-550 and TI-5004.

The fuel gas from the low pressure fuel gas knockout drum to the gas turbine generators can also be heated by the start-up gas turbine heater, 2002-C or 2002CA. The power supply to the electric operated heater is 415 volts, 3 phases, 50H_z. The electric heater is normally used during startup of the gas turbine generator when steam is not available to heat the fuel gas in 2001-C. The fuel gas supplied to the waste heat boiler, the package boiler, the main laboratory, the training building and canteen is reduced in pressure to 7.0kg/cm^{2}g. The fuel gas pressure is controlled to PV-567, on signal from PIC-567. The pressure is also indicated on local PI-567 and PI-568. Natural gas from the fuel gas knockout drum, 2106-F, is also supplied to the NPK unit, the bagging building shrink tunnels, the flame front generator and the burn pit pilot burner.

The fuel gas pressure to these users is reduced to burner. The fuel gas pressure to these users is reduced to 29.3kg/cm^{2}g by pressure regulator, PVC-5139, and pressure control valve, PV-570, on signal from PIC-570. A restriction orifice is also provided downstream of the pressure control valve to reduce the pressure from approximately 29.3kg/cm^{2}g to 8.0 kg/ cm^{2}g. The fuel gas pressure is indicated on local PI-570 and PI-571. A knockout pot is provided downstream of the pressure letdown station to collect any condensed liquid. The condensate collected in the knockout pot is manually drained to the burn pit.

Start-Up Procedures

Nitrogen should be used to replace the air in the system before gas is admitted. When the system is pressured to normal pressure another leak test should be done to be sure the system is free of leaks. The manual block values should be used to control the fuel gas pressure until a constant flow is established to the users. When a flow is established, the fuel gas pressure control values can be placed to regulate the pressure.

Shutdown Procedures

Complete shutdown of the fuel gas system would not be done, except for a complete plant shutdown for turnaround maintenance. One of the gas turbine generators will normally remain in service to provide electrical power for the complex. The fuel gas headers to individual users can be isolated de-pressured and purged when inspection or maintenance is required.

Safety

A fuel gas release due to a blown gasket or defective value would probably require a shutdown of the affected piping. This would also require a plant shutdown if the fuel gas supply to the gas turbine generator or boilers is interrupted. A water spray should be used on the leak area to disperse the gas and reduce the fire hazard as much as possible. All hot work in the area must be stooped and vehicle entry prohibited. If a fire develops in the fuel gas system, the fuel gas supply should be isolated to the affected area. Fuel starvation is the preferred method of fire extinguishing. A Vapour cloud could form and reignite if the fire is extinguished before the fire is gone. Any adjacent vessels containing inflammable material should be cooled with a water spray.

Operating Procedures

(a) Filter Changing

When PDI-562 across the natural gas filters reads 0.35kg/cm2 an alarm condition occurs and the filter must be changed. The following procedure described changing from filter 2018-L to filter 2018-LA. The same procedure applies for changing from filter 2018-LA to filter 2018-l, except the references to PI-599A are transposed together with lines 0-2030-1 ½ and 0-2031-1½. Slowly open the inlet block value to filter 2018-LA and allow the pressure indicated on PI-599 to stabilize. Open the value fully. Open the outlet block valve on filter 2018-LA. Close the inlet and outlet block valves on filter1 2018-L and the 3/4 drain from 0-2030-1 ½. Close the storm water drain at the burn pit, 2401 –B. Close N2 supply valve on N-2016-1". Open the common drain valve on 0-2011-2". Open the drain value at the base of filters 201.8-L and slowly opens the second drain on 0-2030-1 and de-pressures filter 2018-L to the burn pit. When filter 2018-L is completely de-pressured as shown on P1-599 close the common drain valve on 0-2011-2, open burn pit storm drain valve and open the vent valve on top of filter 2018-L. Open the N2 supply valve on N-2016-1" and purge filter. 2018-L to atmosphere until no natural gas can be detected. Close the N2 supply valve. Unbolt and remove the filter top using the davit, and remove the filter elements. Be extremely careful with gasket. Wash the filter in a solution of detergent and hot water. Rinse and completely dry the element. Close the drain value on 0-2030-1 1/2 "and open the ¾" drain value. Hose away any dirt from inside the filter with service water. When both the filter element and the inside of the filter are clean dry, replace the filter element inside the filter and close the ¾" drain value. Refit the head gasket and lid, taking care not to damage the gasket. Purge the filter with N2 as previously described to remove air. When 02 content of the purge gas fails below 20%, close the vent and close the N 2 supply; leaving the filter filled with N2. The filter is now ready for service.

Draining Fuel Gas Ko Drum

There are 3 fuel gas KO drum in the system as follows:-

Number	Location	Pressure
2106-F	Inlet Skid	43.7g/cm2
2111-F	Gas turbine area	20.3kg/cm2
53D25A-3	L.P. Letdown	8.0kg/cm

Their purpose is to retain any natural gas condensates not limited by the external slug catcher or which fall out of the gas as a result of pressure dropping. It is absolutely essential that all possible liquids are removed from the gas streams as they would cause severe damage to plant user equipment. KO Drums, 2106-F and 2111-F, have high level alarms which indicate in the utilities control room. However the operator should not allow liquid levels to rise so high. The following procedure describes the method of draining each K.O. Drum. Open the first drain value nearest to the vessel. Open the first drain value nearest to the vessel. Slowly open the second drain value, monitoring the level gauge on the side of the vessel until all the liquid has gone. Close both drain values. Open the burn pit storm drain value

Burn Pit Operations

The purpose of the burn pit is to safely dispose of natural gas liquids from the three K.O Drums. Should it also be used for burning other materials, instructions will the issued to cover the particular eventuality, e.g. waste all from the oily water separator. The flame front generator, 2401-B2, is installed to provide a safe means of igniting the pilot gas flame. It is supplied with instrument air, fuel gas and electrical power at 240 volts. Air and fuel gas are dropped to a pressure of 0.0kg/cm2 and combined to form a flammable a mixture which is ignited by a spark plug. The flame can be seen in the sight glass on the mixing chamber. The following procedure describes the method of lighting the pilot gas burner and burning K.O. Drum liquids. Open the air supply to PCV-521 slowly to give 0.6kg/cm PI-522. Open the fuel gas supply to PCV-519 slowly to give 0.6kg/cm2 on PI-520. Keep the bypass value closed. Open air and fuel gas to the flame front generator to give half scale readings on the generator pressure gauges. Open the fuel gas supply value to the pilot gas burner on NG-2024-1 ½”. Press the ignition button on the flame front generator and see that a spark is produced and the mixture ignites in the chamber sight glass. It may be necessary to adjust the fuel gas and air values and to repeat the complete sequence. When the pilot flame is established close he supply of fuel gas and air to the flame front generator. Adjust the air mixer on NG-2024-3/4” to give the best flame at the pilot burner tip. Close the burn pit storm water drain value before burning KO drum liquids. The burn pit should only be lit using the flame front generator, particularly if any natural gas liquids are present. Natural gas liquids expand very rapidly to 273 times their volume on igniting and are then completely uncontrollable. Waste oils should not be put in the burn pit when the pilot gas is lit. They should only be put into the burn pit when the pilot flame has been extinguished, the storm water drain value closed and a water seal established in the drain itself Brown *et al*., (1994). Produced wellhead fluids are complex mixtures of Hydrocarbons, and Non-hydrocarbons such as impurities with different Densities Vapor pressure & other physical characteristics

As well streams flows from hot, high-pressure reservoirs, it experiences; Pressure & Temperature Reduction. Gas evolves from the liquid. Well stream changes in character. Velocity of gas carrying liquid droplet, Liquid carrying gas bubbles, and Oil & Gas separator: The terms are oilfield terminology that designates a pressure vessel used for the purpose of separating well fluids into gaseous & liquid components Traps: Stage Separator. Knock-out Vessel or Drum or Trap, used to remove water from well fluids or liquid from gas Water knockout. Flash Chamber: Conventional oil & gas separator operated at low pressure with the liquid from a higher pressure separator being flashed into it. It is often the second or third stage of separation. Expansion Vessel: 1st stage separator vessel on a low temperature or separation unit, sometimes equipped with heating coil to melt hydrate or hydrate preventive liquid such as alcohol or glycol may be injected into the fluid just prior to expansion into the vessel. Filters: (gas filter) could be used to refer to a dry type scrubber, if unit is primarily used to remove dust from the gas stream. Gas

Scrubbers: May be similar to oil & gas separator. It is used to handle fluids that contain less liquid than that produced from oil & gas wells. Gas scrubbers are majorly used in gas gathering, sales and distribution lines where they are not required to handle slugs. Dry type gas scrubbers: Utilizes mist extractors and other internals similar to oil & gas separator. Wet type gas scrubber: Passes stream of gas through a bath of oil or other liquid that washes the dust from the gas. The gas is then passed through mist extractors where all removable liquid is separated from it. The functions of a separator are as follows: Perform primary phase separation. Ensure that gas & liquid flow rate are low enough for gravity segregation & vapor-liquid equilibrium. Minimize turbulence & reduce velocity. Eliminate re-entrainment of separated gas & liquids. Provide outlet for gas with suitable controls to maintain preset operating pressure. Processed gases remove condensable water vapor that might cause hydrate formation. Fluid enters through inlet and hits inlet diverter, causing change in momentum. Initial gross separation of liquid & Vapour occurs at the inlet divert. Liquid droplets, drop out of gas stream to the bottom of vessel due to force of gravity. Retention time required to let entrained gas evolve. Also, provide surge volume if necessary to handle intermittent slugs of liquid. Liquid leaves the vessel through liquid dump valve. Liquid dump valve is regulated by level controller. Gas flows over inlet diverter & then horizontal through gravity settling section. Small liquid droplets entrained in gas are separated by gravity & fall to gas-liquid interface. Gas evolves through mist extractor, lest liquid droplets are finally extracted at mist extractor. Pressure controller, controls the pressure in the separator. If pressure controller senses changes in pressure, it sends a signal to either open or close pressure control valve.

Simulation of The Knockout Drum (Separator)

First natural gas samples was collected from the plant battery limit and was analyzed in the company's Laboratory and the table below shows the result of the analysis in order to determine the percentage component composition of the natural gas feed that is used as feed stock for the Notore plant utility, and Methane usually has the highest composition and based on this month of September analysis because it varies with changes in different upstream production of natural gas processing.

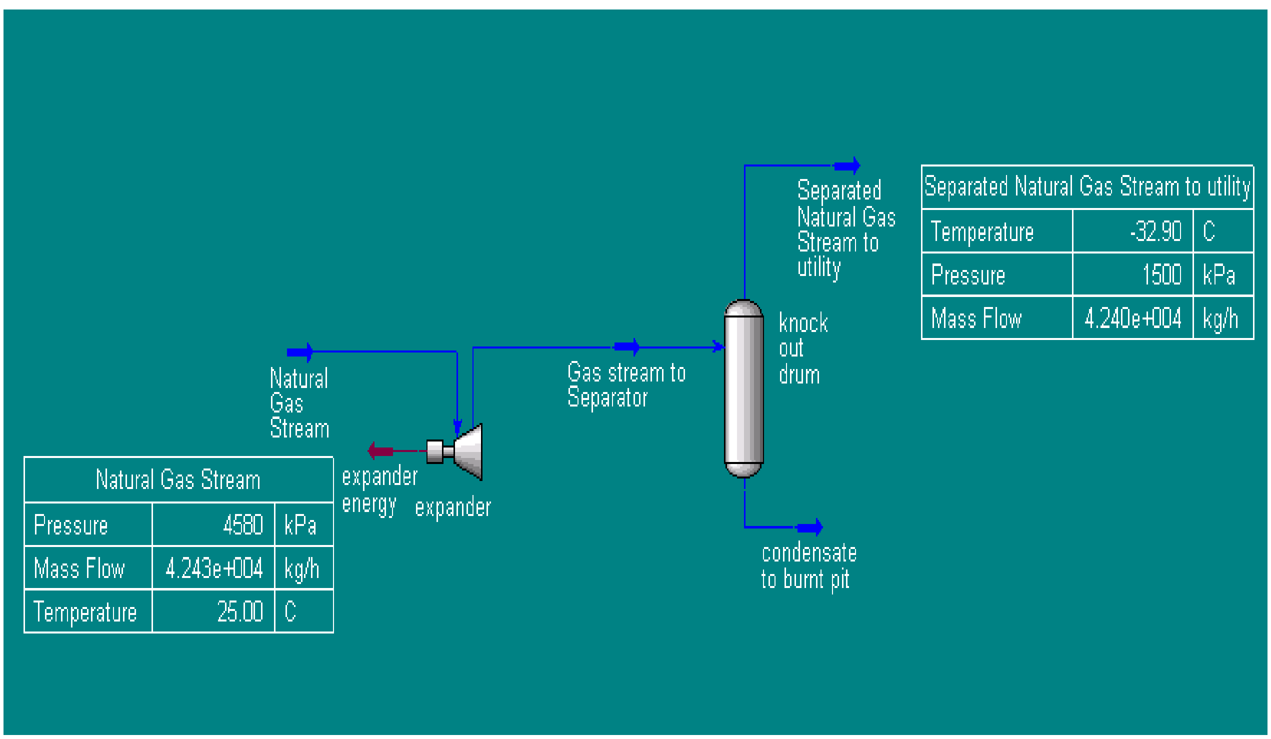
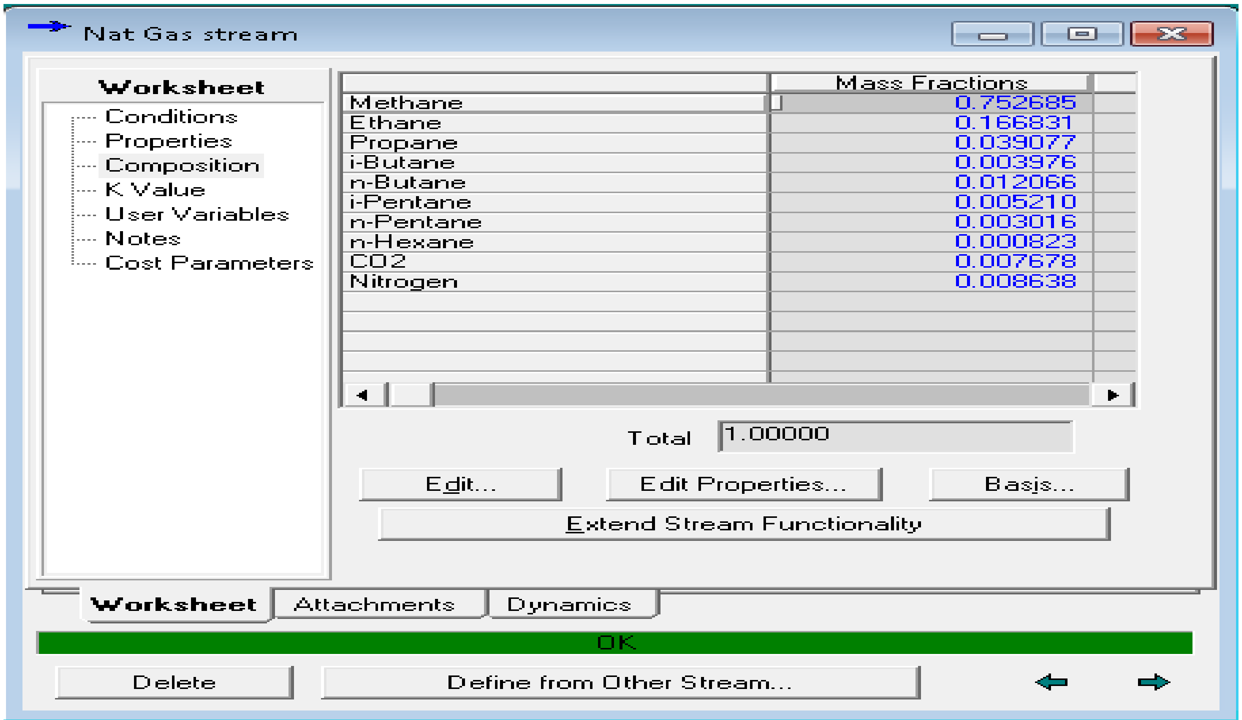


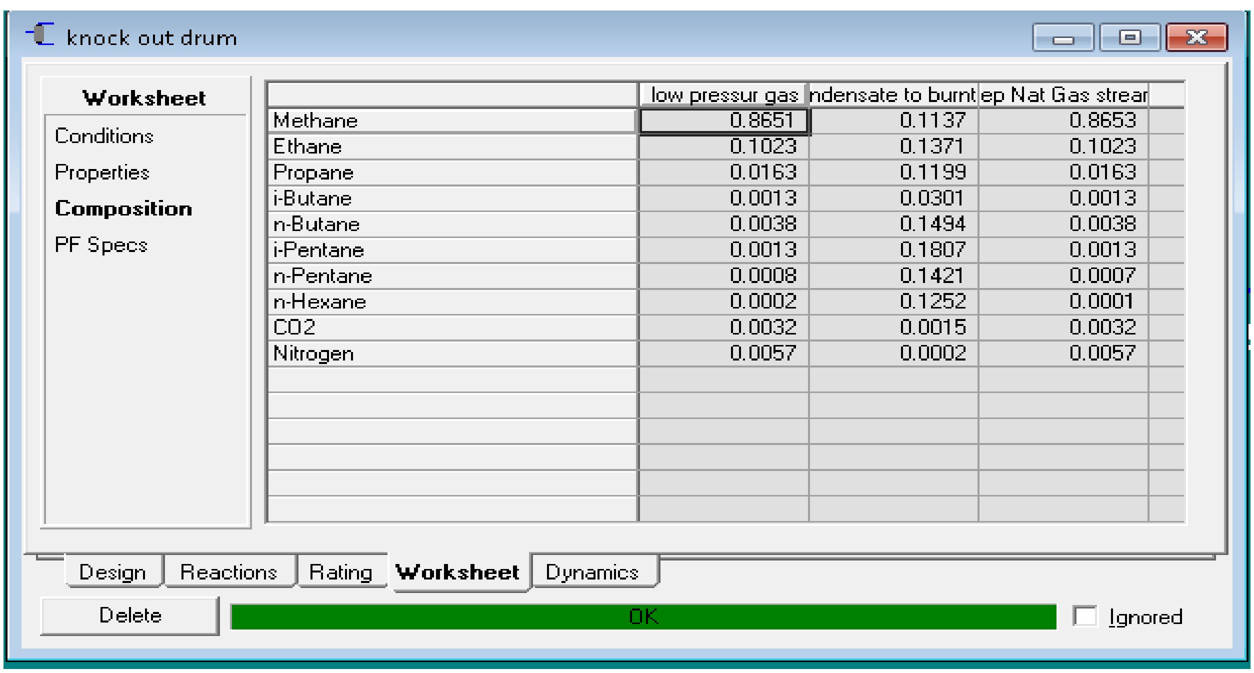
Fig 3.2- Simulated of Conventional knock-out of Notore.



	Mass Fractions
Methane	0.752685
Ethane	0.166831
Propane	0.039077
i-Butane	0.003976
n-Butane	0.012066
i-Pentane	0.005210
n-Pentane	0.003016
n-Hexane	0.000823
CO2	0.007678
Nitrogen	0.008638

Fig 3.3- Simulated Conventional knock-out component compositions

The results of several months analysis was abtained and the worst senero was used for the knockout drum separator simulation, in order to determine the dryness factor of the natural gas. The natural gas analysis for the month of July 2014 is showed in tables 1.2 and is used as the feed for the simulation stream of the knock out drum in order to determine the dryness factor.



	low pressur gas	ndensate to burnt	ep Nat Gas strear
Methane	0.8651	0.1137	0.8653
Ethane	0.1023	0.1371	0.1023
Propane	0.0163	0.1199	0.0163
i-Butane	0.0013	0.0301	0.0013
n-Butane	0.0038	0.1494	0.0038
i-Pentane	0.0013	0.1807	0.0013
n-Pentane	0.0008	0.1421	0.0007
n-Hexane	0.0002	0.1252	0.0001
CO2	0.0032	0.0015	0.0032
Nitrogen	0.0057	0.0002	0.0057

Fig 3.4- Simulated Conventional knock-out condensate and methane

Twister Supersonic Separator

Twister which was developed by Shell Technology Netherland is a low temperature separation process using supersonic gas velocities, with a performance which can be optimized by improved heat integration using the cold gas exiting Twister, supplemented with air or seawater cooling if required. The inlet separator upstream of the Twister tubes is designed to remove produced liquids and prevents carry-over of slugs and solids. The following issues need to be considered when designing a gas conditioning system based on Twister technology. (www.Twister BV.com)**.** Twister is a fixed actual volumetric flow device. The gas velocity at the throat of the inlet nozzle will always be exactly Mach 1, fixing the flow through the tube. Turndown flexibility can be achieved by adjusting the operating pressure or by taking individual Twister tubes on/off line.

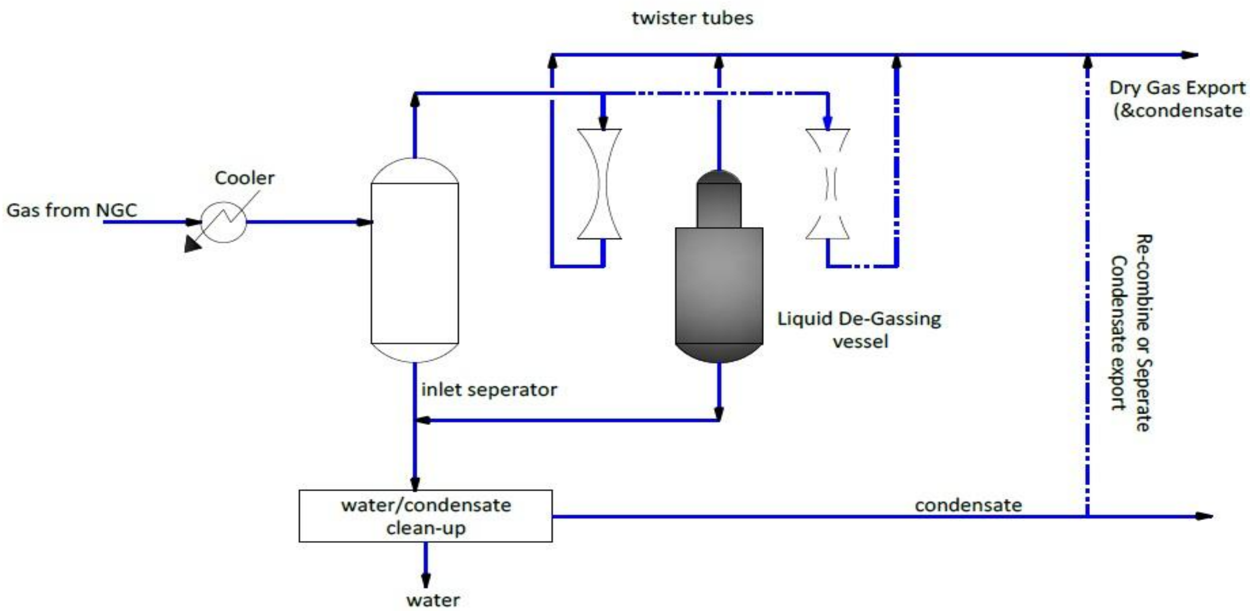


Fig 3.5- Process Flow Diagram of a typical Twister System

This separator is an innovative gas conditioning technology which has been under development for natural gas applications. Condensation and separation at supersonic velocity is the key to some unique benefits. An extremely short residence time prevents hydrate problems, eliminating chemicals and associated regeneration systems. The simplicity and reliability of a static device, with no rotating parts, operating without chemicals, ensures a simple, environmentally friendly facility, with a high availability, suitable for unmanned operation. Full scale testing has been completed at five gas plants in the Netherlands, Nigeria and Norway, with varying gas compositions and operating conditions. The first commercial offshore Twister application started-up in December 2003 on the Petronas/Sarawak Shell Berhad B11 facility offshore East Malaysia. The key challenges and experience gained during the B11 Twister design, and operating experience to date, have resulted in some significant new developments. This includes the low pressure drop version of the Twister Supersonic Separator which also achieves a significantly improved hydrocarbon and NGL recovery performance. This improved performance has been confirmed during testing and details will be presented to describe the development, testing and initial commercialization. Twister also has potential to be further developed for other specific future separation applications, such as deep LPG m extraction, CO_2, H_2S and mercury removal, and for sub-sea gas processing. Although the Niger Delta field bonny light crude is H_2S free hence the designers of the plant included a desulphurizing unit.

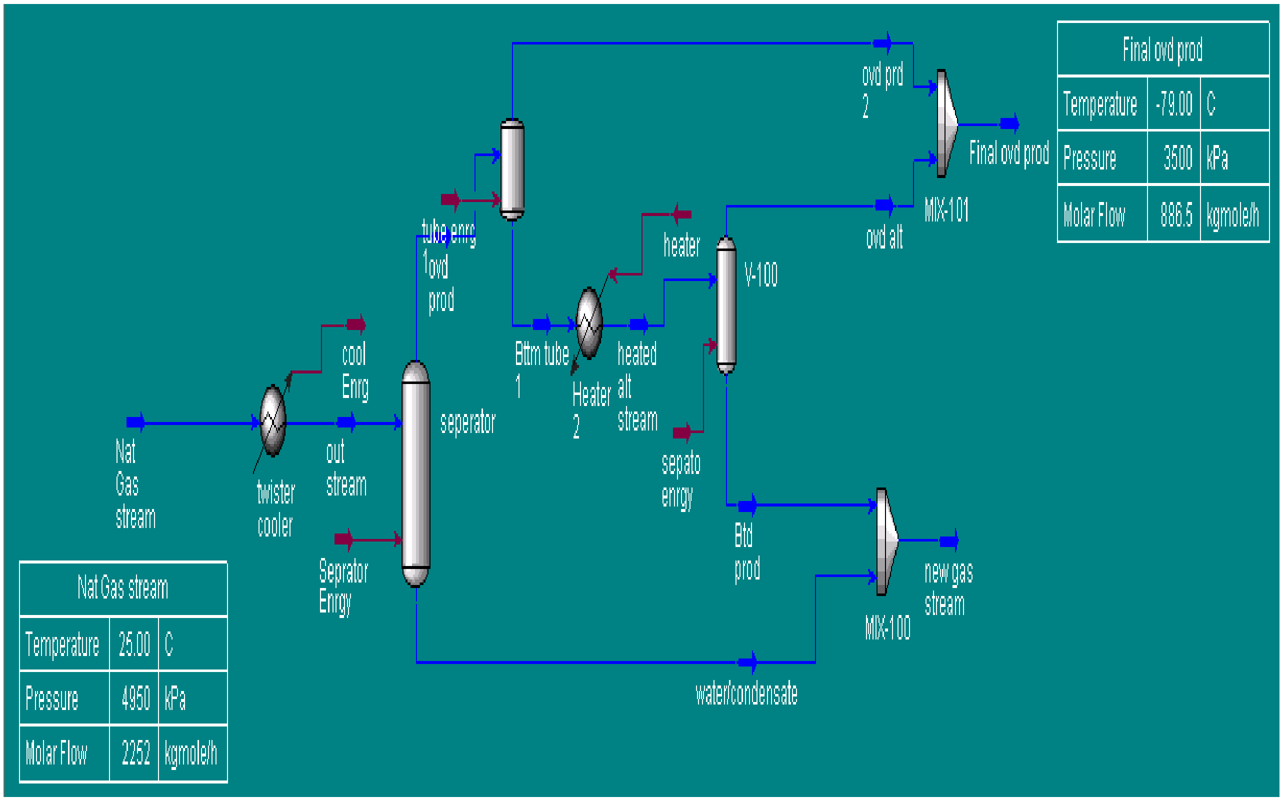


Fig.3.6- Process Flow Diagram of twister Simulation.

The same operating condition and feed was used hence the result below showed that more methane was recovered in this simulation than the previous.

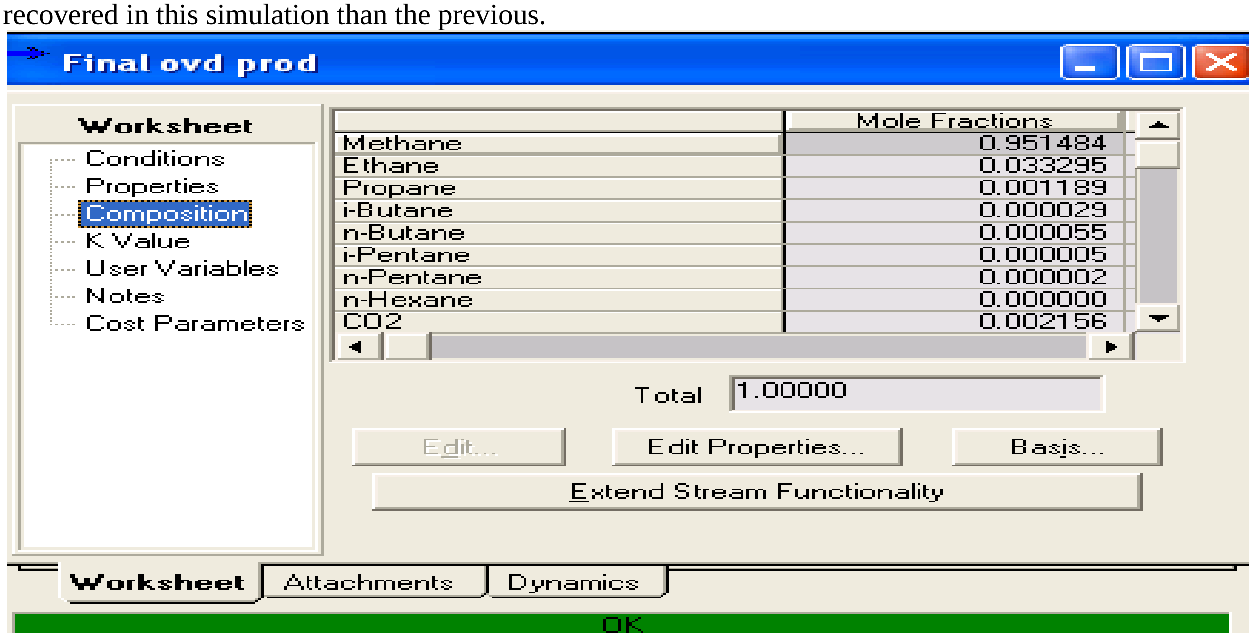


Fig 3.7- Simulation result twister separator

Methane was 95% recovered from the simulation result and the fractions of other components were also shown which is far better than the previous simulation result.

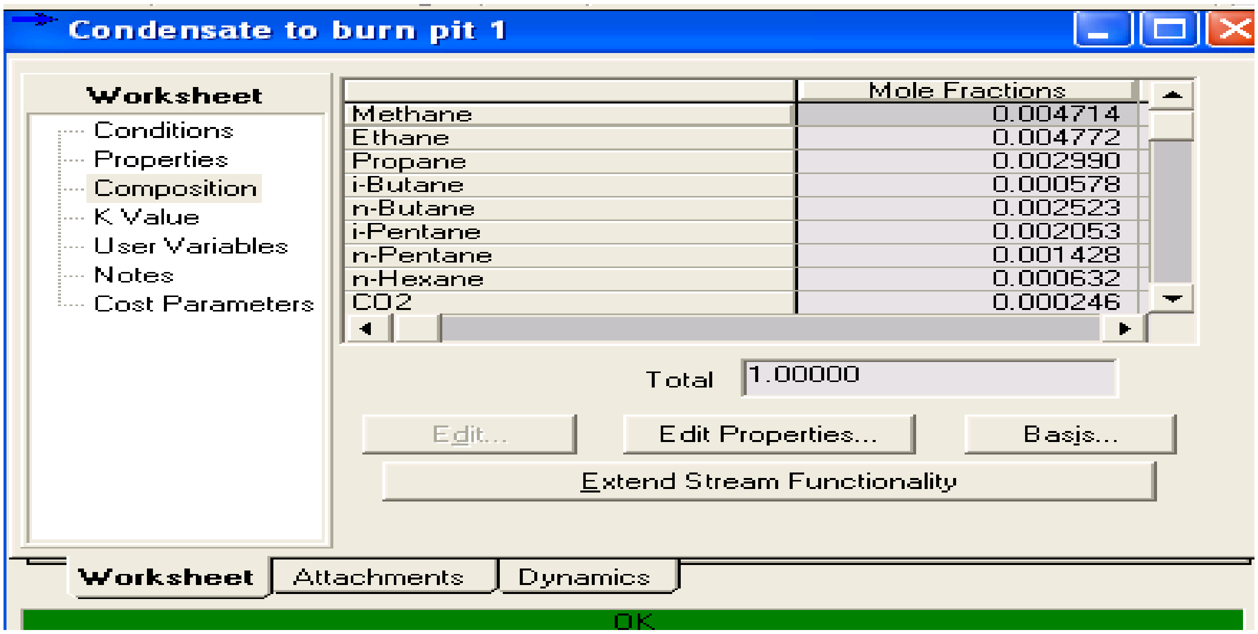


Fig 3.8 Condensate recovered to burn pit

Separated bottom product of condensate to burn pit and the percentage in this case is very small compared to the previous it shows that the separator performance was optimal. The Twister Supersonic Separator has similar thermodynamics to a turbo-expander, combining expansion, cyclonic gas/liquid separation and re-compression in a compact, static, tubular device. A turbo-expander transforms pressure to shaft power; Twister achieves a similar temperature drop by transforming pressure to kinetic energy (i.e. supersonic velocity). The Twister process is a simple, safe, environmentally friendly, quick start up, gas conditioning system which enables chemical free, high availability and unmanned operation. The compact and lightweight Twister system allows the platform size to be reduced which results in an overall lower project cost for offshore applications. The ability to operate unmanned also facilitates significant operating cost savings in allowing the de-manning of offshore platforms. This gas conditioning technology can be used to simultaneously condense and separate water and hydrocarbons from natural gas. Significant potential has been identified for future application of Twister technology for various other gas processing applications including deep LPG extraction, bulk removal of CO_2 and H_2S, mercury removal and sub-sea gas processing. See figure 1 below for a cross-section view of a Twister tube.

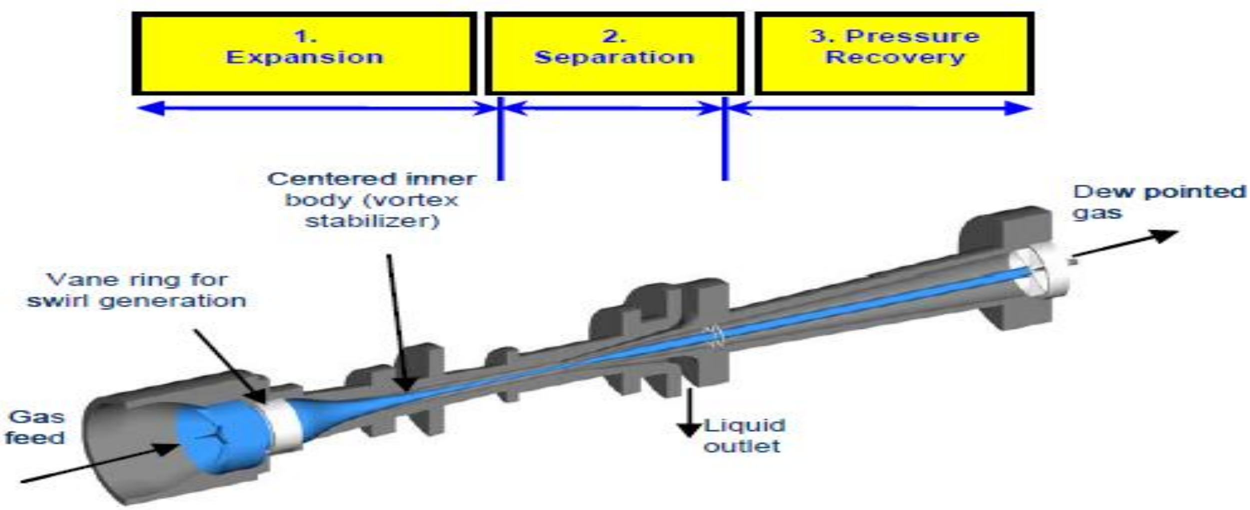


Figure 4: Cross-section of the Low Pressure Drop Twister Tube.

Much lower pressure drop or a significantly improved hydrocarbon separator and NGL recovery performance at the same pressure drop. The improved performance model can achieve a better separation performance at a lower pressure drop than the original design whilst maintaining the original benefits of chemical free operation without the use of moving parts. The more concentric vortex in the Twister tube improves the separation efficiency of the vortex finder with the direct result that a much higher percentage of liquids formed inside the Twister tube are separated from the main gas stream. This explains the improved water separation behavior. However, the same phenomenon also results in enhanced separation of the hydrocarbons which condense inside the Twister tube. Therefore, the optimized design has a greatly improved NGL recovery performance. This also means that the heavier hydrocarbons are separated with a much higher efficiency from the feed gas stream resulting in a step change improvement in the hydrocarbon dew pointing performance.

The Mechanism of Twister Supersonic Separators

The supersonic separator is a revolutionary device which can be utilized to condensate and separate water and heavy hydrocarbons from natural gas. It works mainly on two principles of the gas expansion and cyclone separation. The idea was first patented in 1989 by Stork Product Engineering, as the condi-cyclone, a method to remove water from air by forcing it through a tube at supersonic speed, intended for use in air conditioners (Kontt, 2000). The supersonic separator prevents the hydrate problems and eliminates the needs for inhibitor and regeneration systems due to the short residence time in the device, providing an environmentally friendly facility. As a static device, there are no rotating parts to enable high reliability and availability. Therefore it is suited for unmanned operations, especially for platforms (Okimoto, Brouwer, 2002; Liu, Liu, Feng, Gu, Yan, 2005; Betting, Epsom, 2007; Kalikmanov, Betting, Holten and Veen (2003) proposed a method and apparatus for the separation and liquefaction of the gas mixtures, respectively. There are two structures for the supersonic separators. One is called “Twister I”, in which a swirl generation device is installed in downstream portion of the supersonic nozzle, and the other is named “Twister II” or “3-S (Super Sonic Separator) separator”, where the swirl generation device is installed in the entrance of the nozzle.

Description of Twister Separator

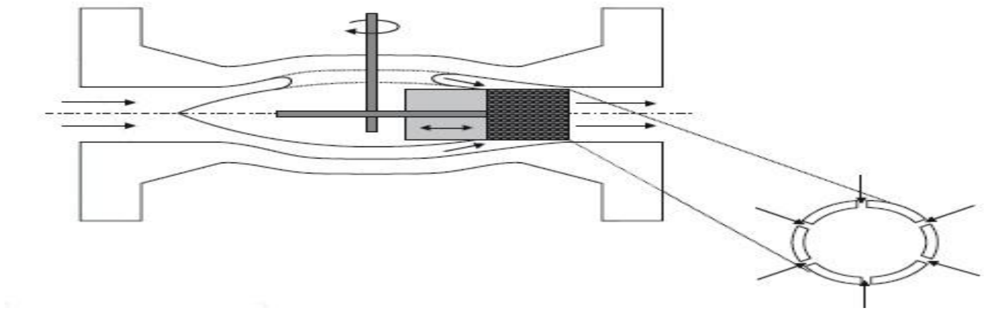
Twister is a proven gas conditioning technology. Condensation and separation at supersonic velocity provides several unique benefits as the short resident time within the Twister tube prevents hydrate problems, the by eliminating the use of chemicals and associated regeneration systems. The simplicity and reliability of this static device with no rotating parts, operating without chemicals, ensure a simple, environmentally friendly, with a high availability, suitable for de-manned operation. The first commercial offshore Twister application on the Petronas/Sarawak Shell Berhad B11 facility offshore East Malaysia has now been in continuous operation, with more than 98% availability, for over four years. A complete Twister gas conditioning module has been supplied to Shell Nigeria for chemical free fuel gas treatment for a gas turbine driven power plant and a contract has been signed with Petrobras for an onshore Twister system. These plants will be commissioned soon.

Applications

Twister can be used to condense and separate water and hydrocarbons from natural gas. Current applications include any combination of the following: Water Dew pointing (Dehydration). Hydrocarbon Dew pointing, Natural Gas Liquids Recovery, Used in Nigeria in two places quote.

Gas Dehydration Using Twister

Gas dehydration using twister follows a series of steps which includes: Standard PFD for Dehydration using Twister technology, optimization parameters – Twister inlet pressure & Temp and Pressure drop, Chemical free process – maintain outlet temperature above hydrate formation temperature. Downstream of Twister tube(s) hydrates are managed by the Hydrate Separator. No hydrates formation occurs within the tube(s). If the water Spec cannot be met, adjust the optimization parameters. Higher inlet pressure improves water removal. Consider optimizing the process with upstream compression and/or downstream compression to meet export gas pressure requirements. Normally upstream compression is preferred. If the water spec can still not be met, consider designing the process with chemical injection to inhibit hydrates by lowering the inlet temperature below HFT.



Fig, 3.9.-Conventional valves for knock out drum internal Mechanism

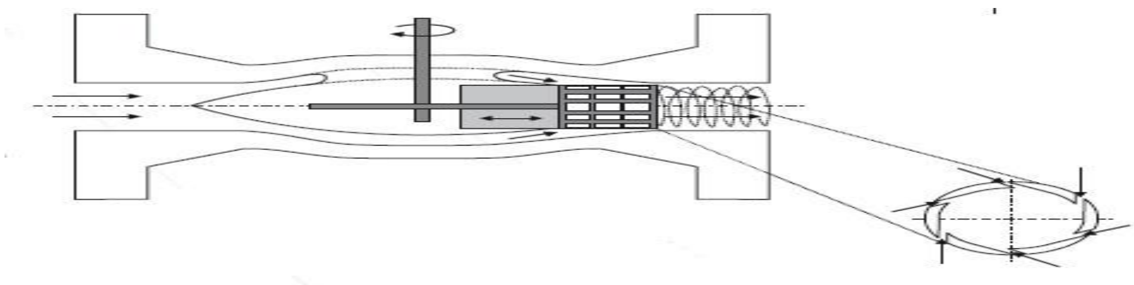


Fig. 3.10- SWIRL valve for Twister separator internal Mechanism

Twister Swirl Value

The twister WIRL Valve improves the HC dew-pointing performance of existing JT-LTS plants: Increases plant flow capacity - Reduces hydrocarbon dew-point. Reduces ΔP required for JT cooling –reduces glycol carry-over. Valves are used in the oil and gas industry to control pressure, temperature and flow. In many cases fluids will expand in the valve, once sufficient pressure drop is created over the valve. This throttling process normally results in a flashed liquid or a condensed gas, which needs to be separated afterwards. A side effect of throttling in choke values is an intensive mixing of the gas and liquid phases, which can diminish the efficiency of the separators downstream of these chokes. The Twister SWIRL valve is a modified choke valve design, which minimizes the mixing of gas and liquid phases and enables agglomeration of the dispersion present after pressure let down. The SWIRL valve uses the available free pressure to create a strong rotational motion in the liquid, resulting in immediate segregation of the formed phases.

Equation of State

An equation of state must be developed to calculate the physical property of fluids in supersonic flows. In this simulation, the ideal gas law and Redlich-Kwong real gas equation of state model were employed to predict gas dynamics parameters. The classical ideal gas law may be written: The Redlich–Kwong equation of state is an equation that is derived from the van der Waals equation Peng, D. Y. and D. B. Robinson, (1976). It is generally more accurate than the van der Waals equation and the ideal gas equation. The Redlich–Kwong EOS can be described as Equation 1.

$$P = \frac{\boldsymbol{RT}}{\boldsymbol{V_m - b}} - \frac{\boldsymbol{a}}{\sqrt{\boldsymbol{TV_m}}(\boldsymbol{V_m + b})} \quad (1.)$$

Where *p* is the gas pressure, *R* is the gas constant, *T* is temperature, *Vm* is the molar volume (*V*/*n*), *a* is a constant that corrects for attractive potential of molecules, and *b* is a constant that corrects for volume. The constants *a* and *b* are different depending on which gas is being analyzed, which can be calculated from the critical point data of the gas: Where, *Tc* and *pc* are the temperature and pressure at the critical point, respectively.

$$a = \frac{0.4275\ R^2\, T^{2.5} T_C^{2.5}}{P_c}$$

$$b = \frac{0.08664 R T_c}{P_c} \qquad (2.)$$

From the Notore Chemical industry's operation condition and parameters, the following values were given in order to determine the

Where: T = 24^{0}C (298k)

$P_{c\,=}$ 33.8 N/M^2

T_c = 723K

R = 8.314J/K

V_m = 0.4852m^3/kg mol (3.)

$$a = \frac{0.4275.\ \ (8.314)^2 (723)^{2.5}}{3.38}$$

$$b = \frac{0.08664\ \ (8.314)^2 (723)}{3.38}$$

$$a = 12288113.168$$

$$b = 15.408$$

$$p = \left(\frac{8.314.298}{0.4852 - 15.408}\right) - \frac{12288113.168}{\sqrt{298}(298 + 0.4852)}$$

$$p = \left(\frac{8.314.298}{0.4852 - 15.408}\right) - \frac{12288113.168}{\sqrt{298 \times 0.4852}(298 + 0.4852)} \qquad (4.)$$

$$\underline{p = \ 166.0259\ 3423.6855}$$

Twister value added

Twister BV has developed the SWIRL Valve using our extensive knowledge of expanding multi-phase flows. This knowhow has been gained during the 10-year development of the Twister supersonic Separator. Twister BV has therefore bridged the instrumentation discipline (which specifies valves in process modules) and the process engineering discipline (that specifies the separation performance of vessels, but not the flow details inside the valve). Twister BV offers tailored SWIRL valve designs that meet specific customer performance criteria.

SWIRL Valve applications

SWIRL Valves can be applied in the following production scenarios: Joule Thomson expansion of gas flows. Flashing oil/condensate flows in stabilization processes. Oil/water separation processes. When applied to existing facilities, the application of SWIRL Valve technology offers: Flow debottlenecking of separator trains. Reduced pressure drop in JT-LTS processes. Less liquid carry-over/gas carry-under, higher liquid recovery reduced chemical loss.

The Twister Swirl Valve Working Principle

Tangential slots in the cage valve trim forces the choking flow into a strong rotational motion, causing small droplets to concentrate and agglomerate along the perimeter of the pipe wall. The free pressure energy is dissipated through dampening of the vortex along the extended pipe length downstream of the valve. The advantage of creating a swirling flow in the valve is twofold: Regular velocity pattern>less interfacial shear> less droplet break-up> larger drops, concentration of droplets in the circumference of the flow area> increased number density> improved coalescence>larger drops. The flow is normally throttled over a perforated cylinder (cage).

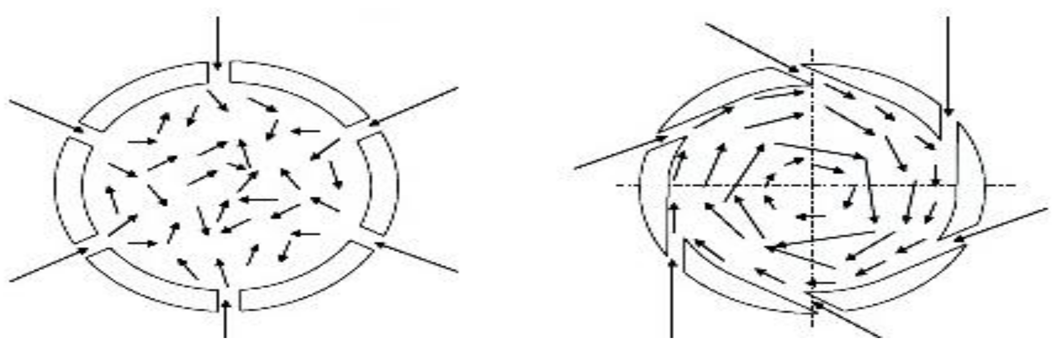


Fig. 3.11- conventional valve and SWIRL valve qualitative pattern.

These perforations, either slots or holes, normally have radial orientations which are perpendicular to the cylinder surface. Two phase flow simulation has been performed to assess the segregation performance of the SWIRL Valve compared to a conventional valve operating at a feed pressure of 100bar and a back pressure of 65 bar. The above figures show the liquid volume fractions of a fine dispersed liquid phase in a gas flow, typical for a Joule Thomson process. The liquid dispersion in the SWIRL Valve is agglomerated along the circumference within 3 pipe diameters.

4. Results

Result of Natural Gas Recovered

From the simulation using Aspen Hysys package, it was seen that the Twister supersonic gas separator is more efficient than the knockout drum separator. Less methane and less condensate was produced using knockout drum separator at 0.699% and 0.092% respectively while the Twister supersonic gas separator produced methane and condensate at 95.15% and less condensate 0.0047% respectively. The table below shows the comparison of result of the knockout drum separator against the Twister Supersonic gas separator performance and from the results shown using Twister Supersonic Gas separator produced more methane of 0.951484.

Comparison of Knockout Drum Separator and Twister Separator Performance				
	Twister Separator		Knockout Drum Separator	
Natural Gas	Mol % of Final Overhead	Mol % Water/Condensate	Mol % of Final Overhead	Mol % Water/Condensate
Methane	0.951484	0.004714	0.699338	0.092079
Ethane	0.033295	0.004772	0.234642	0.272916
Propane	0.001189	0.00299	0.034914	0.201253
i-Butane	0.000029	0.000578	0.002291	0.040413
n-Butane	0.000055	0.002523	0.00615	0.171895
i-Pentane	0.000005	0.002053	0.001236	0.115318
n-Pentane	0.000002	0.001428	0.000591	0.07442
i-Hexane	0	0.000632	0.000042	0.022726
Carbon dioxide	0.002156	0.000246	0.007468	0.003096
Nitrogen	0.011785	0.000015	0.013281	0.000433

Table 4.1-Simulation Test Results of twister and knockout drum.

The table 4.1 shows the level of methane recovered using twister supersonic gas velocity as against the conventional installed knockout drum and this was possible because of the mechanism governing the two different separators, the performance of the supersonic gas flow velocity is as a result of the gas liquid cyclone tube installed inside pipe-in-pipe swirling valve that swirl the flow of the natural gas from subsonic velocity part of the channel and then accelerating it to supersonic velocity, when the static temperature of the gas becomes lower than the condensation temperature. The use for an extractive device for separating the condensed droplets of one the targeted component, which in this case is methane, is therefore separated and the condensate is then dispersed.

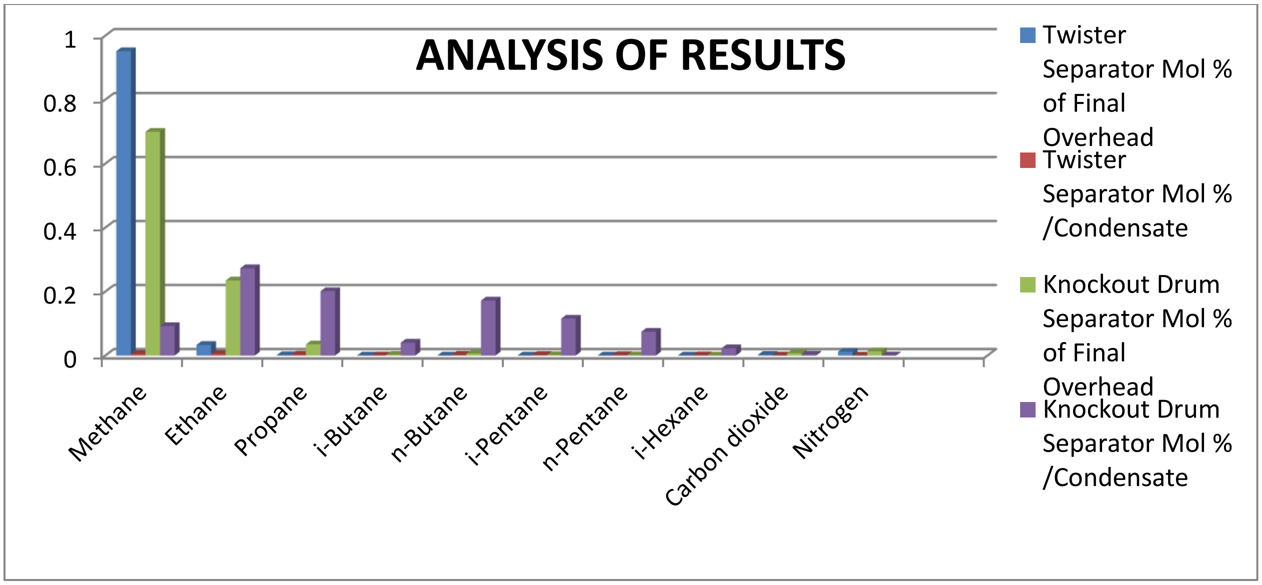


Fig. 4.1 Graph of twister and knockout component separation.

Simulation of Twister Operator Results

The graph showed the result of both separators overhead products and bottom products respectively and it is confirmed that twister supersonic gas velocity flow recovered the highest percentage of methane which is our main target for the plant as the installed knockout drum is inefficient.

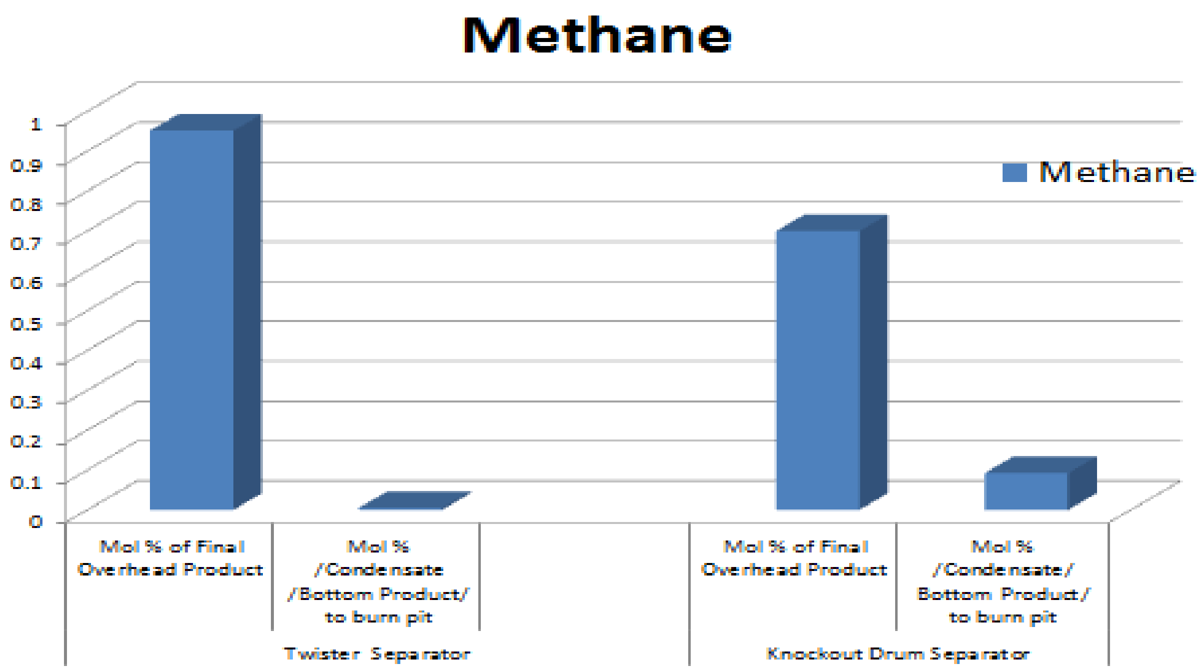


Fig 4.2 Graph of Methane Composition in Each Stream

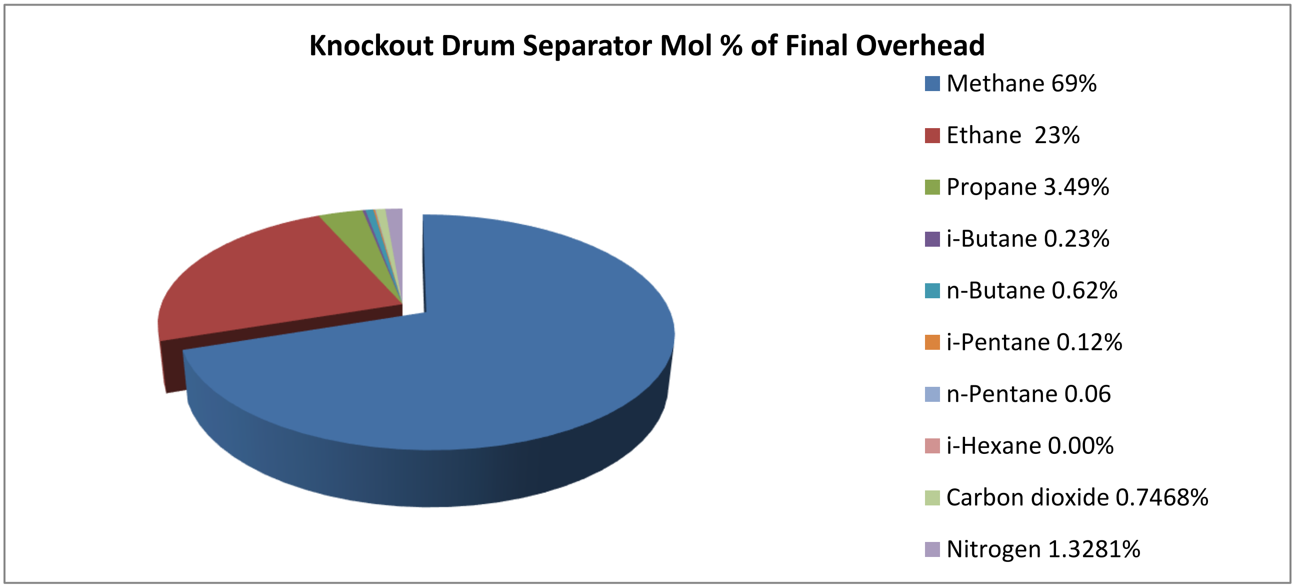


Fig 4.3- Knockout Drum Separator Mole % of final Overhead.

5. Conclusion

Through a comprehensive analysis of its operational principles, design considerations, and field performance, this study demonstrates how the Twister system can outperform traditional methods in terms of recovery efficiency, energy consumption, and operational footprint. Numerical simulations and case studies are used to highlight the system's effectiveness under varying field conditions, providing valuable insights for optimizing gas processing operations. The findings presented offer a novel approach to gas-liquid separation that can significantly enhance production capacity and support sustainable development goals in natural gas extraction. the basis for simulation in order to obtain the results. From the simulation results of both separators, Twister supersonic gas separator is more efficient than the knockout drum separator because Methane losses using the Twister supersonic gas flow separator is less when compared with the Methane losses using the knockout drum separator. Result indicates that Twister supersonic gas separator is more efficient than the knockout drum separator. Less methane and less condensate was produced using knockout drum separator at 0.699% and 0.092% respectively while the Twister supersonic gas separator produced methane and condensate at 95.15% and less condensate 0.0047% respectively. The results presented offer a novel approach to gas-liquid separation that can significantly support sustainable development in natural gas utilization.

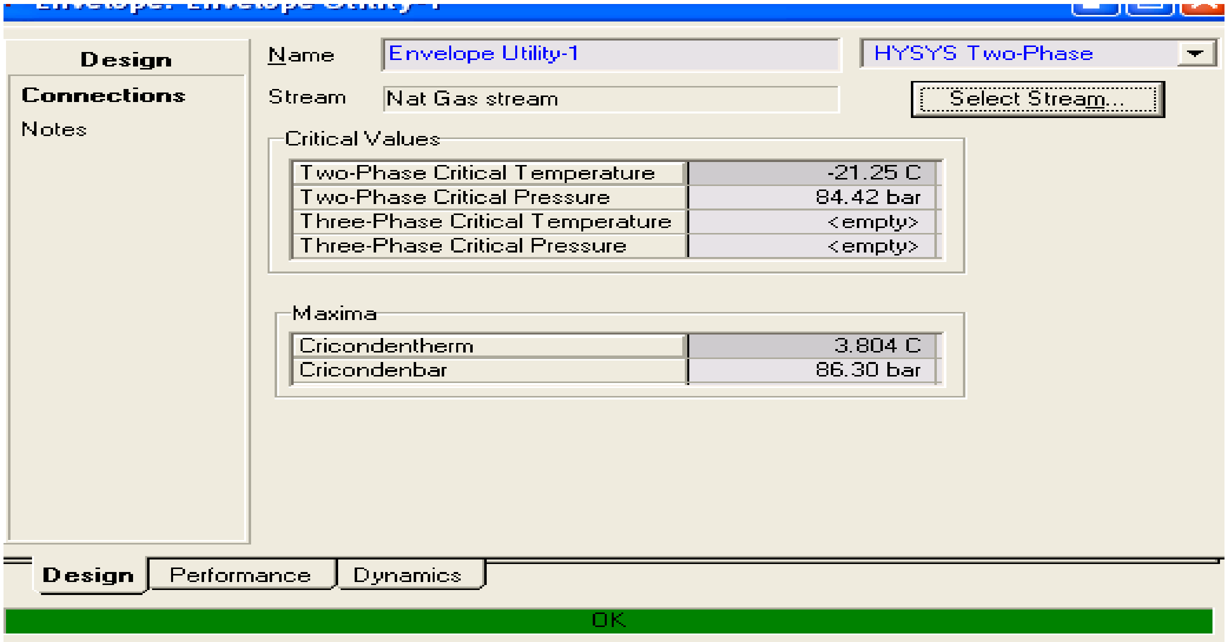


Fig-5.1- Phase Envelope Natural Gas Stream Utility

To reduce frequent down-time of the company and increase productivity and turnover Twister is better. And from the results also water was 100% removed from the system by the supersonic gas separator and the plant in any way will not be effected by as by liquid carryover or gas blowby from the inlet of the supersonic gas separator while for the knockout drum separator.

6. Recommendations

Further works should be done on the economic analysis aspect of this thesis work which was basically technical, in order to determine the profitability of using the twister supersonic gas separator against the existing knock out separator. I recommend the use of twister supersonic gas separator for Notore because of its long run benefit in minimization of risk, hazards, and maintenance schemes costs. Also the potential benefits of this work will not only be for Notore but other process plants that uses gas as there feed stock, e.g. Petrochemicals plant, fertilizer plant, power plant (gas turbines), refineries and liquefied natural gas etc.

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Nomenclature

p	=	gas pressure
R	=	gas constant
T	=	Temperature.
V_m	=	Molar Volume
P_1	=	Pressure of gas at pipe inlet psia
P_2	=	Pressure of gas at pipe inlet psia
LCV	=	Level Control valve
Q	=	Gas rate SCF/Dm3/D
PIV	=	Pressure indicator valve
P_c	=	Critical pressure
G	=	Gas specific gravity
Z	=	Average gas compressibility
T_c	=	Critical temperature
F	=	Fraction factor
b	=	Constant that corrects for volume
R_e	=	Reynold’s number dimensionless
V	=	Fluid velocity
G_1	=	Mass flow rate kg/s
$\triangle P$	=	Pressure drop KN/m^2 (Pk_a)
a	=	Constant that corrects for attractive potential of molecules
μ	=	Fluid viscosity, poise
f	=	Gas density kg/m^3
SRK	=	Soave Redlich Kwong