

Supersonic Separation of Natural Gas Liquids by Twister Technology

Arash Esmaeili

Saipem Contracting Nigeria Limited, Process Engineering Department, Port Harcourt, River State, Nigeria
 Arash.esmaeili2010@gmail.com

The Twister supersonic separator is a unique combination of known physical processes, combining aerodynamics, thermodynamics and fluid dynamics to produce an innovative gas conditioning process. Condensation and separation at supersonic velocity is the key for achieving a significant reduction in both capital and operating cost. Twister is a proven gas conditioning technology. Condensation and separation at supersonic velocity provides several unique benefits as the short residence time within the Twister tube prevents hydrate problems, thereby eliminating the use of chemicals and associated regeneration systems. A Twister tube designed for 1 MMSm³/d (35 MMSCFD) at 100 bar is approximately 2 m long. The simplicity and reliability of this static device with no rotating parts, operating without chemicals, ensures a simple, environmentally friendly facility, with a high availability, suitable for de-manned operation. Twister can achieve both water and hydrocarbon dew pointing in one unit. The supersonic separation equipment has thermodynamics similar to a turbo expander, combining cyclone gas/liquid separation and re-compression in a compact, tubular device.

Processing of natural gas is the largest industrial gas separation application. The U.S consumption of natural gas is higher than 623 billion SCM/y and total worldwide consumption surpasses 2.69 trillion SCM/y. This consumption drives a worldwide market for new natural gas separation equipment of more than \$5 billion per year. Natural gas contains many contaminants, water being the most common undesirable component. Most natural gases will be nearly water-saturated at the temperature and pressure of production. Dehydration of natural gas is hence a critical step of the natural gas conditioning process as it reduces the potential for corrosion, hydrate formation and freezing in the pipeline. A conventional method for dehydration in the natural gas industry is the use of a liquid desiccant contactor-regeneration process by TEG. However, there are several operating problems with glycol dehydrators. Suspended foreign matters may contaminate glycol solutions and overheating of the solutions may produce decomposition products. Foaming of solution may also occur with resultant carry-over of liquid. Besides water contamination, natural gas contains liquids that should be commonly removed to meet hydrocarbon dew point specification. An undesirable result of extracting NGL is a lower heating value of the gas product which can reduce its market value. In this paper, Twister supersonic technology is evaluated and compared to conventional Joule-Thompson valve and Turbo-expander.

1. Introduction

A separator is used to separate gas, oil and water from the fluids produced in oil and gas fields. Vessel separators are large, heavy and expensive in terms of the space that they occupy on offshore platforms. Kalikmanov et al. (2007) reported one attractive alternative appears to be the use of gas-liquid cylindrical cyclone (GLCC). For this device the oil and gas phases are also already in equilibrium before entering the separator. It is essentially a cylindrical pipe in which a mixture of gas and liquid in thermodynamic equilibrium are injected tangentially, thereby causing a vortex. The gas-oil mixture is thus separated by centrifugal and buoyancy forces. The cylinder has two outlets, at the bottom and at the top, used for oil and gas respectively. In such a device, the feed stream is generally a single-phase multi-component gaseous mixture containing

condensable vapours. The gas flows through a separation section, representing a Laval Nozzle, at supersonic velocity. The main physical processes are:

- Multiple static inlet guide vanes generate a high velocity, concentric swirl: while the gas is entering the nozzle, is traveling at subsonic velocities. The swirling motion is generated by a vane ring at the entrance of the Laval nozzle. The swirl strength increases strongly, due to contraction in the nozzle, resulting in a centrifugal field of about 500,000 g (Gravity) based on Betting and Epsom (2007) studies.
- A Laval nozzle (an aerodynamically shaped venture tube) is used to expand the saturated feed gas to supersonic velocity by a near isentropic expansion with efficiency more than 80 %, which results in both low temperature and pressure. When the diameter of nozzle reduces the gas is forced to accelerate until it reaches the nozzle throat. In the throat the cross sectional area is the smallest and the gas velocity becomes sonic. From the throat, the area increases and then leading to the expansion of the gas and the velocity becomes progressively more supersonic. This nozzle is a tube that is pinched in the middle and with the shape of an hourglass so that uses Joule-Thompson effect as a principle. During expansion sufficient temperature drops occurs to reach the T_{dew} of the water vapour in natural gas as per Gonzalez et al. (2012) research.
- This results in the formation of a mist of water and hydrocarbon condensation droplets which are at high super saturation condition: Homogeneous nucleation of vapours induced by the fast expansion resulting in the formation of fine mist of sub-micron (usually, Nano-sized) clusters, which then grow by means of diffusion and coalescence and/or coarsening (Ostwald ripening) to macroscopic droplets
- The high velocity swirl forces the droplets to the wall.
- The liquids are removed from the gas using a cyclonic co-axial separator, at this point the total fluid velocity is around 400 m/s resulting gas residence time less than 2 ms: Separation by inertia of the droplets heavier than the surrounding gas due to a strong swirling flow. Two operational plants successfully dehydrated wet gas in the Netherlands and Nigeria achieving a dew point of -30°C and -40 °C respectively.
- In order to recover the initial pressure of the gas, a shock wave is generated. To obtain shock wave the velocity must change from supersonic to sonic speed. The separated streams are slowed down in separate diffusers, typically recovering 80 - 85 % of the remaining free pressure: the remaining kinetic energy in the separated flow streams within the tube is transformed to increased static pressure in the diffuser section; this enables either the installation of a compression system to be postponed or the compression costs to be reduced according to Betting and Epsom (2007) reports.
- The liquid stream contains slip-gas which is removed in a compact liquid degassing vessel and recombined with the dry gas stream

2. Process Evaluation

The Twister supersonic separator has similar thermodynamics to a turbo-expander based on Schinkelshoek (2008) studies. 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 is a fixed actual volumetric flow device; the gas velocity at the throat of the inlet nozzle will always be exactly Mach 1.0 fixing the flow through the tube. The compact and lightweight Twister system allows the platform size to be reduced which results in an overall lower project cost for offshore applications. This conditioning technology can be used to simultaneously condense and separate water and hydrocarbons from natural gas. Based on the current performance, the upgraded technology can be applied for more stringent gas processing specifications where water dew point suppressions of more than 25 °C are required, in addition to achieving chemical-free dehydration at a lower pressure drop without the use of moving part as well as avoidance of harmful BTX to the atmosphere, Twister is introduced as an environmental friendliness and no emission technology. Significant potential has been identified for application of Twister technology for various other gas processing applications including deep LPG extraction, bulk removal of CO₂ and H₂S, mercury removal and sub-sea gas processing. Figure 1 shows the cross sectional area of Twister tube.

Twister BV, launched in April 2001 and the first commercial offshore Twister application on the Petronas/Sarawak Shell Berhad B11 facility on East Malaysia was installed in December 2003 and has now been in continuous operation with more than 98 % availability. This unit consists of 12 tubes dehydrating up to 600 MMSCFD of sour gas on the platform. The benefits of sub-sea gas conditioning may include: elimination of surface facilities, avoidance of riser systems, improved hydraulic performance of pipeline, slug prevention, hydrate prevention, corrosion prevention, pipeline cost savings and unmanned operation. Two complete Twister gas conditioning modules have been supplied to Shell Nigeria for chemical-free fuel gas treatment for

a gas turbine driven power as well as Southern Swamp Associated Gas Solution (SSAGS) gas plant project which contains six identical Twister tubes for gas conditioning.

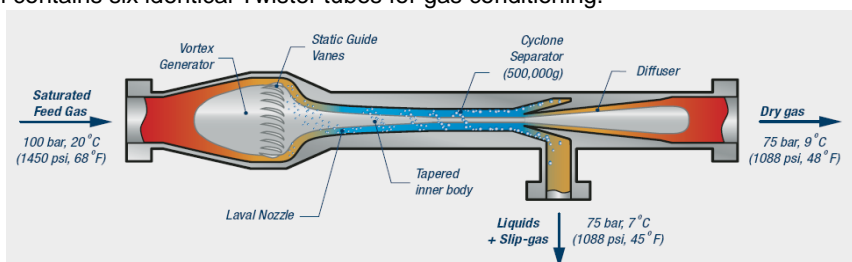


Figure 1: Cross-section of Twister Tube

Whereas a Twister shows a higher NGL recovery for the same pressure drop compared to the JT system, this can also be used to reduce the pressure drop for the same performance as JT system. The availability of partially dehydrated gas and or hydrate inhibition chemicals enables the Twister system to expand much deeper into the phase envelope than the JT system. Twister can maximise its heat integration since the gas-gas heat exchanger of a JT system is always much larger than for a Twister system. Even though an turbo-expander has a similar isentropic expansion to a Twister tube, thus enabling a lower pressure drop than a JT valve for a similar expansion, expander will have the same limitations as a JT system with regards to the minimum acceptable temperature in the LTS. Twister in combination with the hydrate separator therefore has unique advantage over the turbo-expander and in many cases a 10 - 20 % higher efficiency than a turbo-expander, by being able to replace JT valves in brownfield applications where gas conditioning at a lower pressure drop is required. Figure 2 depicts the comparison between Twister and JT valve to decrease temperature.

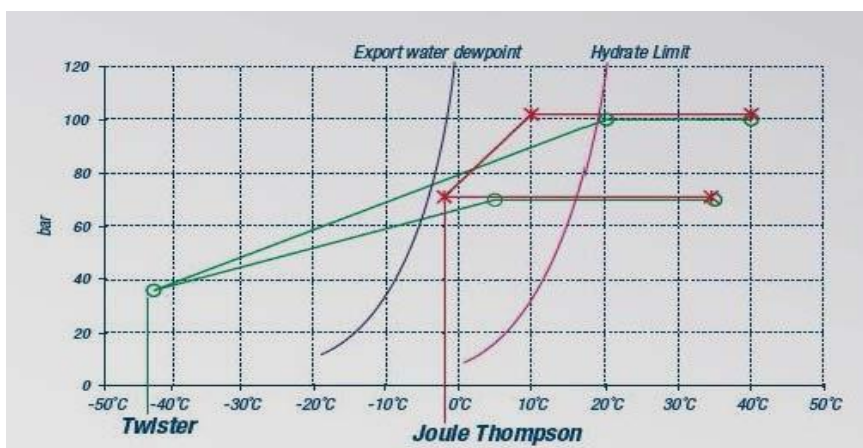


Figure 2: The comparison of thermodynamics between Twister and conventional Joule-Thompson expansion

The improvement in performance is especially great at higher feed pressures and for leaner feed gas. With a feed pressure of 100 bar and downstream pressures of 55-75 bar the improvement is typically around 0.8-1.0 t/MMSCF more LPG and 15-20 bbl/MMSCF greater NGL recovery. With a feed pressure of 70 bar and downstream pressures of 40-50 bar the improvement is typically around 0.4-0.6 t/MMSCF more LPG and 5-10 bbl/MMSCF greater NGL recovery. At low feed pressures the benefit of Twister over the JT is eroded. At a feed pressure of 40 bar and downstream pressures of 20-30 bar, when expansion is inefficient as outlet pressure is below the cricondentherm pressure, the NGL yields of the two processes are similar, though the Twister starts to outperform the JT for lean gas for higher pressure losses.

For lean gas, the recovery with Twister is typically five to ten times as great as with the conventional JT scheme while the JT recovery only approaching the recovery same as Twister when the feed water content is very low. As the water content in the feed gas increases, the hydrate formation temperature rises and less heat integration is possible, this means that NGL recovery for the water saturated feed is far lower than for bone dry gas (without the use of chemicals). This has a greater impact on the JT system as the hydrate formation temperature limits the operating temperature in the LTS, whereas the hydrate formation temperature only limits the Twister system at the inlet as hydrates are not formed in the Twister tube due to the very short

residence time and any hydrate formation in the secondary outlet of the Twister tube is managed in the hydrate separator. The difference between the two processes is clearly illustrated by Figures 3 and 4, which show that LPG recovery with a Twister is typically 35.7 t/MMSCM higher than with a JT and LPG recovery which is typically 85 - 113 m³/MMSCM greater. Table 1 also describes the difference of both devices.

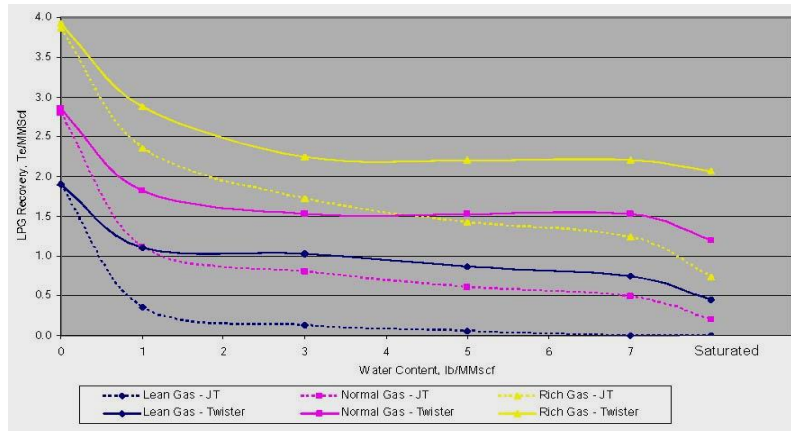


Figure 3: LPG recovery per MMSCF Gas vs. water content, inlet pressure 100 barg, inlet temperature 35 °C, 45 % pressure drop

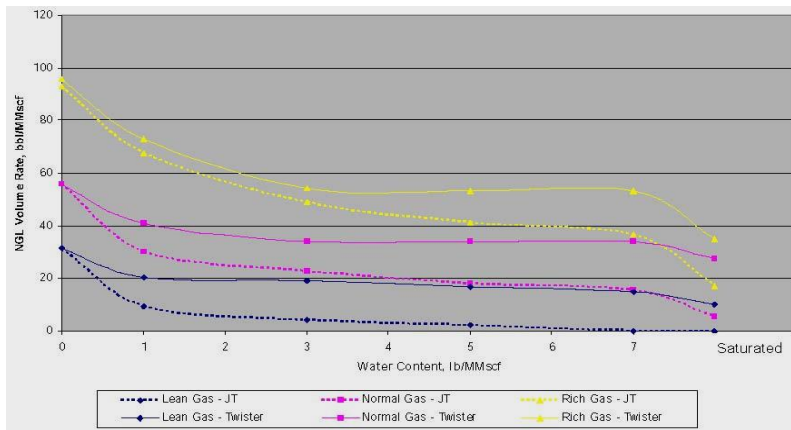


Figure 4: NGL recovery per MMSCF Gas vs. water content, inlet pressure 100 barg, inlet temperature 35 °C, 45 % pressure drop

Table 1: The comparison of conventional JT/LTS process with Twister Technology by Machado et al. (2012)

Process	Advantages	Disadvantages
TEG + JT/LTS	<ul style="list-style-type: none"> Simple and compact process Ease in operation Low capital cost Low maintenance cost 	<ul style="list-style-type: none"> Hydrocarbon dew point control is directly related to the pressure reduction cross Joule-Thomson (JT) valve Off-spec gas during start up Sensitive to feed gas composition
Twister	<ul style="list-style-type: none"> Can achieve dehydration and dew point control simultaneously Remove more hydrocarbons than JT valve for the same pressure drop Compact module design Ease of installation and operation Low maintenance cost 	<ul style="list-style-type: none"> High compression horsepower for deeper hydrocarbon recovery Limited commercial test experience and performance relies on proprietary information Limited turndown without operator involvement

The corresponding absorption contactor would be 5 m in height and 1.4 m in diameter and the corresponding adsorption line would be composed of two adsorbers 3 m in height and 1 m in diameter.

3. SSAGS Gas Plant Simulation

The southern swamp area comprises fields within oil mining license (OML) 35 and OML 46 in the coastal swamp area in Nigeria. All existing production in the area is gathered into four stations at Tunu, Ogbotobo, Benisede and Opukushi. The produced oil is evacuated via pipeline to the terminal and associated gas is currently flared (earlier 2016).

The primary function of the central processing facility (CPF) is to end routine flaring of the flow stations and develop concept now called Southern Swamp AG solutions (SSAGS) with the flow rate 15, 8.5, 17.8 and 27.5 MMSCFD for Tunu, Ogbotobo, Benisede and Opukushi respectively. AG production rate is dependant by the oil production and cannot be regulated; AG slug catcher pressure is maintained by back pressure from the suction pressure control of the AG compression train. Non associated gas (NAG) production rates can be adjusted by remotely controlled automatic chock valves and the relevant slug catcher pressure is maintained by adjusting the NAG production. NAG and AG gases are comingled upstream of the first stage Twister separator, gases from this separator passes via gas/gas and gas/liquid heat exchangers to the second stage separator which is then sent to the Twister unit. The Twister unit provides for gas dew pointing control and dehydration. The Twister assembly consists of six tubes which are essentially fixed flow devices. Export compressor boosts the gas to the export pipeline pressure; export compression consists of two parallel centrifugal trains each with two stages which are able to operate in series or parallel arrangement.

In order to compare Twister tube, turbo-expander and JT valve, one expander module of HYSYS has been used to change the efficiency within 96 %, 75 % and 1 % for each one respectively. Our evaluation shows using expander by efficiency 1 % can act as a JT valve to reach the same expansion and temperature in the same pressure drop (48.5 bar). Figure 5 illustrates the temperature reaches from 31.7 °C in upstream to 14 °C, 3 °C and zero after passing JT valve, turbo-expander and Twister tube.

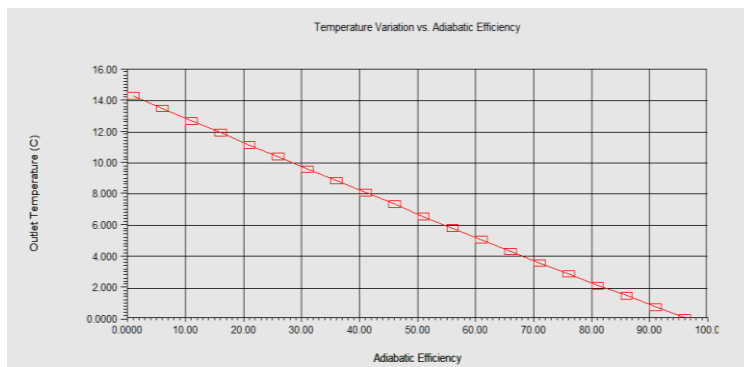


Figure 5: Temperature variation versus adiabatic efficiency of Turbo-expander

Figure 6 measures the gas and liquid flow rate in Hydrate separator when efficiency changes between 0 - 96 %. As is seen, by pressure drop from 110 barg to 61.5 barg and decreasing temperature the liquid recovery is rising and thus dry gas with no liquid is increasing.

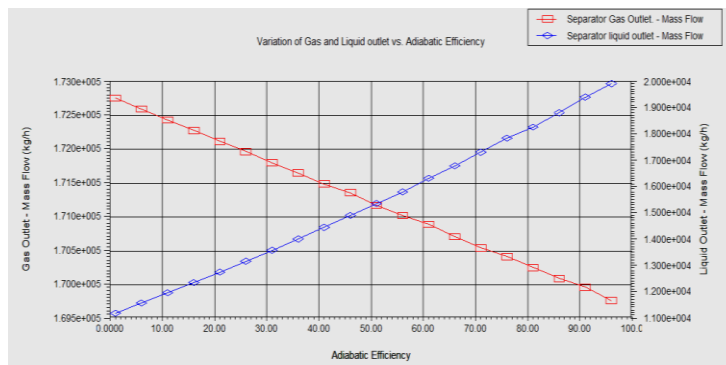


Figure 6: Gas and Liquid flow rate of Hydrate Separator versus adiabatic efficiency of Turbo-expander

The variation of water, LPG and NGL recovery is shown in Figures 7 and 8. By increasing expansion and temperature drop, the water content as well as LPG and NGL content in the gas outlet of hydrate separator is sharply decreasing and recovered liquid is gathered in the bottom of separator for further processing.

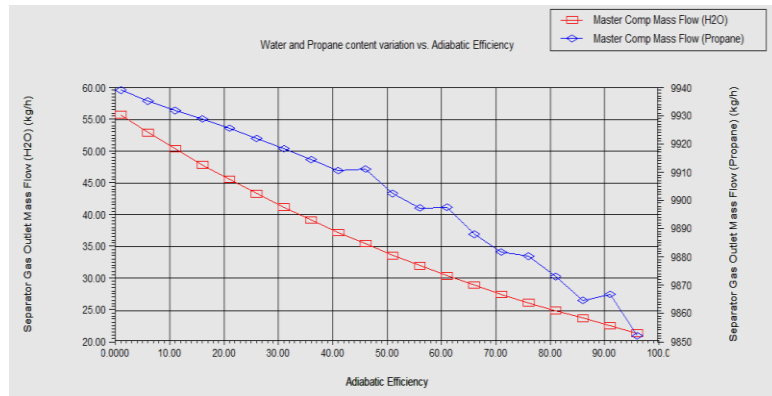


Figure 7: Water and Propane flow rate of Hydrate Separator Gas outlet versus adiabatic efficiency of Turbo-expander

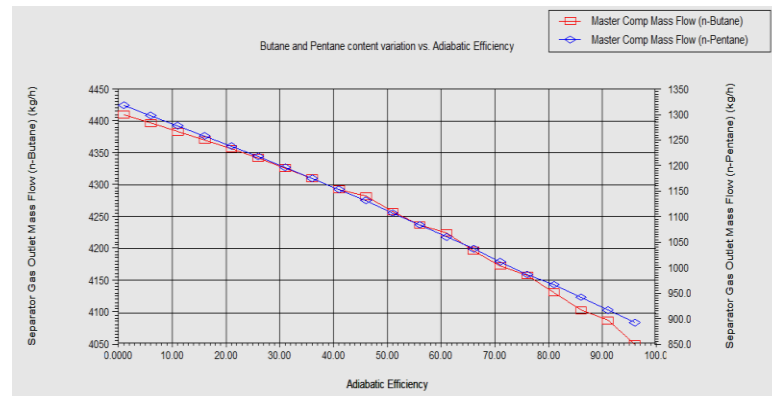


Figure 8: Butane and Pentane flow rate of Hydrate Separator Gas outlet versus adiabatic efficiency of Turbo-expander

4. Conclusions

Twister technology has same advantages of JT valve and expander plus some other positive points e.g. compact configuration and lower capital and maintenance costs. Twister can reach the same expansion and temperature drop in comparison with JT valve in the lower pressure drop and make deeper expansion and LPG recovery in the same pressure drop with JT valve. Twister tube has similar isentropic efficiency with expander but can makes lower temperature and more NGL and liquid recovery.

References

- Betting M., Epsom H., 2007, Supersonic separator gains market acceptance, World Oil, Gulf publishing company, 197-200, Texas, USA.
- Gonzalez T., Netusil M., Dittl P., 2012, Raw Gas Dehydration on Supersonic Swirling Separator, Technical Transactions Mechanics, Prague, Czech Republic.
- Kalikmanov V., Betting M., Bruining J., Smeulders D., 2007, New developments in nucleation theory and their impact on natural gas separation, SPE Annual Technical Conference and Exhibition, 11-14, Texas, USA.
- Machado P.B., Monteiro J.G.M., Medeiros J.L., Epsom H.D., Araujo O.Q.F., 2012, Supersonic separation in onshore natural gas dew point plant, Journal of Natural Gas Science and Engineering, 6, 43-49, Rio de Janeiro, Brazil.
- Schinkelshoek P., Epsom H.D., 2008, Supersonic gas conditioning-Commercialization of Twister technology, 87th annual convention, Grapevine, Texas, USA.