THE USE OF NEW ADSORPTION TECHNOLOGY

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Summary

Adsorption is widely used in Gas Dehydration. Recently, new technology has been applied by using a new type of silica gel adsorbent for both gas dehydration and hydrocarbon dew pointing. A study to evaluate the different methods of hydrocarbon dew pointing was performed by Enppi and proved that the use of adsorption process with a new type of silica gel has significant cost benefits over the life of field.

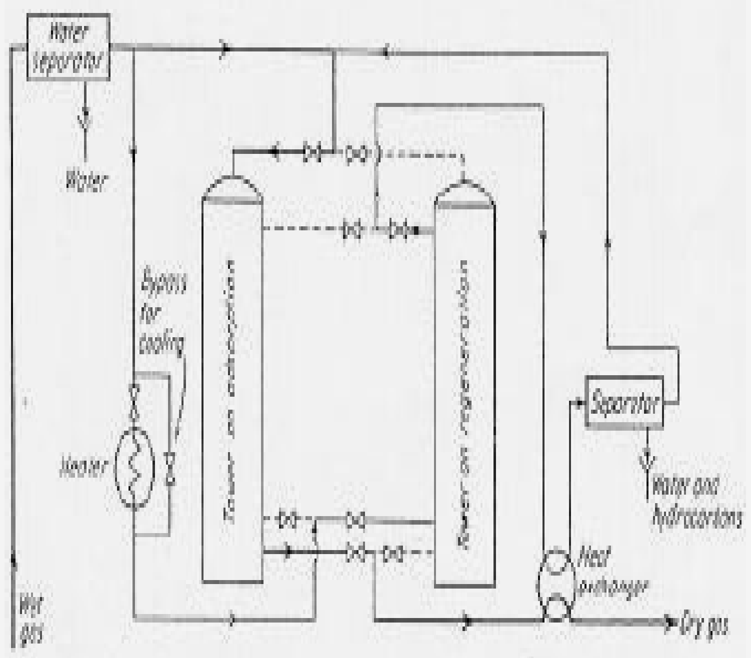
In Egypt, this new technology has been used in the Rosetta gas plant, which was designed for 302 MMSCFD (275 + 10%). The plant has been operational for about 4 years and experience demonstrated that the new type of silica gel has high performance, excellent reliability and low operating cost. Following these good results, the plant has been tested up to 380 MMSCFD and again the adsorbent proved its high performance and efficiency.[1]

Introduction

Adsorption is the process by which molecules of a liquid or gas contact and Adhere to a solid surface. Adsorption is used for dehydration in addition to a variety of air Pollution control problems.

Adsorbents are very porous materials that contain many miniscule internal pores. The total surface area is enormous – 0.1 to 1.0 km2/kg or 20 to 200 football fields per kilogram. Pore sizes are as small as nanometres. The most common configuration for industrial adsorbers involves the use of fixed bed adsorption systems. A schematic diagram of a typical fixed bed system is shown in (Figure 1).

In oil and gas industry adsorption is widely used for water dew-pointing, recently adsorption has been used for both water and Hydrocarbon Dew-pointing. This paper presents a case study of the new technology applied for the first time in Egypt in the Rosetta Gas field.



Flow diagram for solid desiccant dehydration.

(Figure 1)

Definition of Adsorption

Selective adsorption concerns the separation of components in a fluid mixture by the transfer of one or more components (the adsorbates) to the internal surface of a porous solid (the adsorbent) where they are subsequently held by intermolecular forces. The fluid may be a gas, vapor or a liquid.

Desorption is the reverse process in which the adsorbates are removed from the adsorbent surface so that the adsorbent is regenerated for re-use. Thus, adsorbents are characterized by surface properties including surface area and polarity. Practical adsorbents are inert and are relatively easily regenerated for re-use. There are two main methods of regenerating the adsorbent:

1. Temperature Swing Adsorption (TSA) in which an increase in temperature is used to desorb the adsorbates
2. Pressure Swing Adsorption (PSA) in which a decrease in pressure is used to desorb the adsorbates.

The former method is usually employed in natural gas processing where a proportion of the plant feed gas is frequently used as the regenerating medium. The use of heat as the regenerating mechanism avoids the large pressure drops required for PSA systems, with associated costs in re-compression of the regeneration feed gas.

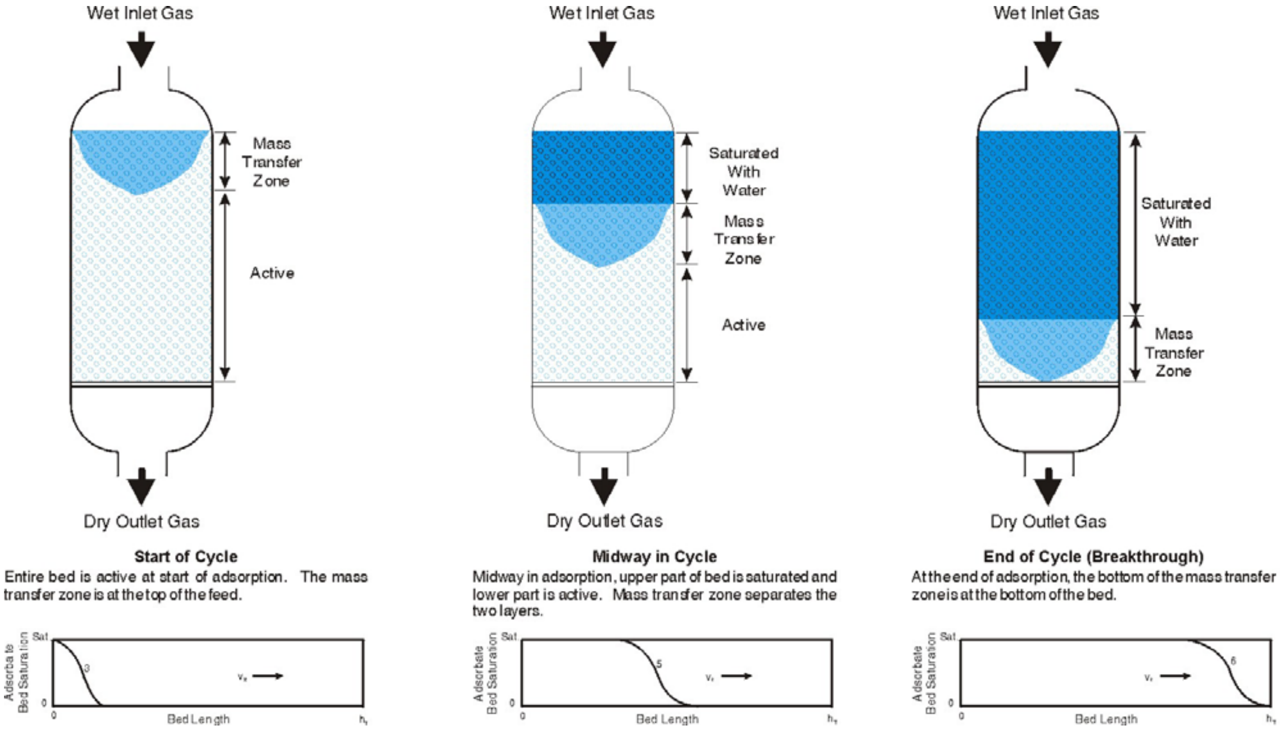
The adsorption units designed by BG Technology (Advantica) using the ADAPT (ADsorption APplication Technology) process utilise Temperature Swing Adsorption. To cater for the processing duty required for the Rosetta field development, a two bed adsorption system has been specified, with one bed operating on adsorption (operating half a cycle out of phase) and the second bed on regeneration.

The adsorption process is cyclic, with process gas sent to the online bed (a packed tower containing the adsorbent material) which acts to adsorb the water and heavier hydrocarbons from the process gas. thereby lowering the water and hydrocarbon dew points of the gas leaving the towers   The beds have a fixed capacity for the adsorbed species, and once saturated with water and heavy hydrocarbons, feed gas is re-directed to another bed whilst the original bed is regenerated for re-use using hot feed gas (regeneration gas).

Mechanism of Adsorption

Adsorption as a process is considered to be similar to condensation, as electrostatic forces pull molecules out of the fluid phase. To promote adsorption of selected components, preferable conditions are saturation conditions, often at elevated pressure and ambient temperature. Heat is produced as a result of adsorption (the heat of adsorption) and is analogous to the latent heat of condensation. As the adsorption process proceeds, the bed saturates progressively from the inlet to the outlet. Thus the portion of the bed containing the mass transfer zone (MTZ, illustrated as having a gradient of adsorbate concentration decreasing from saturation to zero) moves towards the bed outlet.

When the mass transfer zone reaches the outlet, breakthrough of the adsorbate component occurs and the bed is no longer able to retain all of the adsorbate present in the feed gas. Eventually, the outlet concentration of the adsorbate in the outlet will equal the inlet concentration because the mass transfer zone has completely passed through the bed and the bed is said to be exhausted. (Figure 2)



Adsorbent Materials - Silica Gel

There are a wide range of materials including molecular sieves, carbon, xeolites and silica gel which can be used in adsorption processes. However, the preferred material for combined hydrocarbon dewpoint control and water removal is silica gel.Silica gel is a partially dehydrated form of polymeric colloidal silicic acid, with the chemical composition SiO2-«H2O. The water content occurs mainly in the form of chemically bound hydroxyl groups and typically accounts for around 5 wt% of the material.

The new types of adsorbent used the in Rosetta gas plant are :

Sorbead H (also known as KC-Trockenperlen H)removes heavy (C6+) hydrocarbons from natural gas and moisture. simultaneously .This reduces the hydrocarbon and water dew points, preventing liquid deposition in gas pipelines, and enables the extraction of natural gasoline.

Sorbead WS (also known as KC-Trockenperlen WS) is the a water-resistant adsorbent with a high adsorption capacity. It is most frequently used as a protective layer in combination with Sorbead R, Sorbead H or Sorbead Plus or even other adsorbents, such as molecular sieves. For very severe operations with frequent liquid slugs, Sorbead WS's high capacity enables it to be used on a stand-alone basis.

Case study - Rosetta gas plant

Why Adsorption?

The Rosetta Field Development consists of an offshore platform where bulk water is removed from the hydrocarbons, a sub sea pipeline to shore, and an onshore processing plant where the gas is conditioned to sales gas specifications and the condensate is stabilized. Onshore and offshore gas compression is required later in field life as the reservoir pressure declines.Process simulation work has been carried out with the Rosetta Field development Basis for Design.

CASE **NOMINAL**	**NUMBER** **MMSCFD**	**1** **275.0**	**2** **275.0**	3 385.0
COMPOSITIO	**UNITS**	**MOL** %	**MOL** %	**MOL** %
H2O N2 CO2 C1 C2 C3 IC4 NC4 IC5 NC5 C6 C7 C8 C9 C10 **C11** +		0.0320 0.0752 0.7072 94.7654 3.6254 0.1448 0.2898 0.0556 0.1454 0.0262 0.0635 0.0468 0.0148 0.0033 0.0039 0.0007	0.0637 0.0751 0.7075 94.7465 3.6296 0.1453 0.2910 0.0558 0.1453 0.0261 0.0617 0.0401 0.0095 0.0015 0.0012 0.0001	0.0604 0.0751 0.7075 94.7541 3.6297 0.1452 0.2909 0.0558 0.1445 0.0260 0.0605 0.0388 0.0090 0.0013 0.0011 0.0001
TOTAL		100.0000	100.0000	100.0000
- FLOWRATE - FLOWRATE - MOLECULAR WEIGHT -C5+ -C5+ -C6+ -C6	KMO1/h KG/h - MOL % WEIGHT% MOL % WEIGHT%	13781.0 236312 17.146 0.305 1.460 0.133 0.738	14121.3 241897 17.129 0.310 1.414 0.126 0.682	19610.7 335899 17.127 0.281 1.311 0.111 0.593
- - PRESSURE - PRESSURE Through the	°C BARA BAR	16.9 79.5 5	34.8 79.5 5	34.7 85.4 5

Evaluation of alternative Hydrocarbon and Water Dew Pointing Methods.

The four processes considered were:

- Adsorption using Silica Gel,
- Joule-Thomson Expansion across a valve.
- Turbo Expander (isentropic expansion using turbine)
- Mechanical Refrigeration.

For the purpose of this technical evaluation production rate of 275 MMSCFD at end of P1 plateau (onshore compression required) has been used as the basis for all simulation work as it represents the plateau flow rate of 275 MMSCFD, at the lowest onshore arrival pressure, giving the maximum onshore compression duty.Four process options for water and hydrocarbon dew pointing the export gas have been modeled using Pro/11 and conditions established that allow the export gas specifications to be met. The simulation results indicate that all four processes are suitable for meeting the specifications.

The Joule-Thomson, Turbo expander and Mechanical Refrigeration options rely on the cooling of the gas plus the injection of MEG or similar to remove the heavy hydrocarbon components and the water and thus meet the dew point specifications.

For the Joule-Thomson Expansion option, this involves additional compression of the gas with the low temperature achieved by pressure letdown across a valve. Similarly for the Turbo Expander, additional compression is required with the expansion occurring across a turbine rather than a valve. Some of this power is recovered in the compressor and therefore the additional power required is lower than the Joule-Thomson option. For Mechanical Refrigeration an external refrigeration package provides the cooling.

For the Joule Thomson and Turbo Expander options, the Rosetta inlet compressor would be required earlier than currently scheduled based on the use of the adsorption process.

Silica Gel Adsorption relies on the affinity of the heavy hydrocarbon components and the water for the silica gel which preferentially removes them from the export gas. The beds are regenerated by the addition of heat via a slip stream of heated product or feed gas.The Advantica Silica Gel Adsorption method, being the preferred option in previous studies has been compared with other adsorption processes to confirm its applicability. This comparison shows that the Advantica process is the preferred method for fluids having the composition of the Rosetta gas.

The power requirement for each of the four processes under consideration is given in the following table:

Option	**Inlet compressor power**		**Refrigeration power required (KW)**
	power required (KW)	**power above base case (KW)**	
J-T Valve	16,734	1,516	
Turbo Expender	15,799	581	
Mechanical Refrigeration	15,037	-181	1,350
Silica gel adsorption (base case)	15,218	0	

The three cold processes investigated require additional power, for the Joule-Thompson and Turbo Expander options there is additional gas compressor power and for Mechanical Refrigeration there is refrigerant compression.

The silica gel process, whilst having no additional power requirements, does require a significant amount of fuel gas for the Regeneration Heater. On this basis fuel gas requirements are similar for all processes investigated.The three cold processes require either TEG or MEG injection for hydrate inhibition and water removal. MEG dehydration has been assumed for company purposes. Although costs for the two processes have been reported to be similar. MEG has been reported as equivalent to US$50,000 per annum. This evaluation has been performed on a technical basis with no operation taken as to the economics of any of the options. However, previous work performed as part of the development of the conceptual design for this project concluded that the Silica Gel Adsorption process provides a life of field cost saving of approximately US $52 million when compared to the Mechanical Refrigeration option.[2]

Adsorber Tower

The towers are packed, internally insulated pressure vessels, rated to the maximum operating temperature expected during regeneration of 275°C. During both adsorption and regeneration, gas flows downwards through the beds to avoid possible fluidization of the silica gel packing. The silica gel packing consists of two layers of differing material. At the top of the bed, a small layer of silica gel grade W is provided, with the main packing of Silica gel grade H filling the majority of the vessel internal volume. The grade H material is the main adsorbent and is tailored to remove heavy hydrocarbon and water components from the incoming gas.

The grade W material is supplied to act as a guard layer and is more mechanically resistant to breakage in the presence of free liquids.Whilst care is taken in designing the feed gas filter/coalescer to stop free liquids entering the bed, the guard layer provides a second barrier to free liquids damaging the main charge of grade H material. A schematic diagram showing the internals of a typical adsorber vessel is shown in (figure 3). There are several features of the internal layout which should be considered during the design/specification of the pressure vessel:

1. The charge of silica gel grade H is supported on a series of layers ofceramic balls, above the bed support plate. Graduating the ceramic ballsfrom around 1" down to l/2" allows for a degree of settling early in the units life without allowing the silica gel to pass down towards the support plate and helps to minimizes the amount of dust generated by attrition at the base of the bed.

2. An alternative to the arrangement shown at the bottom of the vessel is tosurround the outlet nozzle with ceramic balls, thereby avoiding the use of a bed support plate. Consideration should be given to the total mass of ceramic balls that may be required before selecting this option as the balls act as an efficient heat sink during regeneration and can have an impact on the time to cool the bed down at the end of the regeneration cycle.

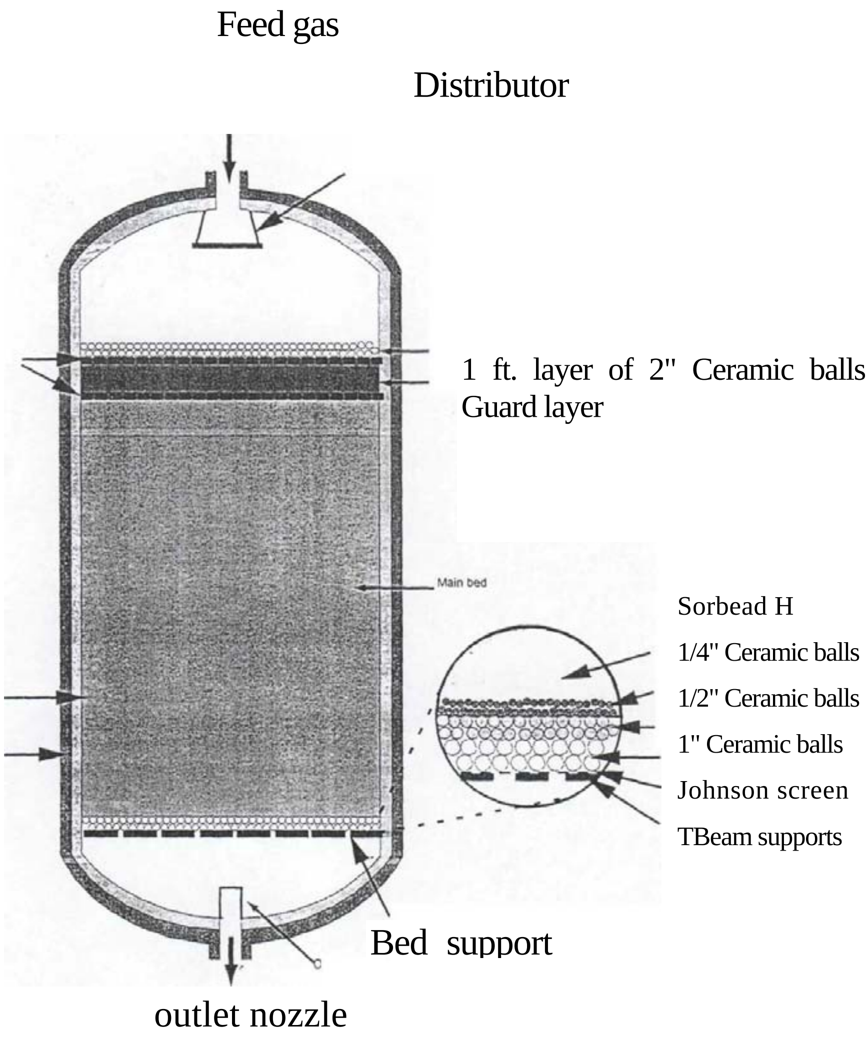
3. At the top of the bed, a fine wire mesh is used to separate the guard layer and the main charge of adsorbent form a protective layer of ceramic balls. This layer is used to minimize the effect of impingement by the feed gas and to minimize the disturbance of the beds in the event of back pressure.

4. BG Technology strongly recommend the provision of a man way entry at the bottom of the vessel, to assist with the initial charging and subsequent discharge/recharging operations required when changing the adsorbent.

5. Access to the top of the vessel will be required to rake level the top layer of silica gel and allow the ceramic balls to be placed. If the feed nozzle is too small to allow access, a second man way at the top of the vessel will be required.

6. Provision of a distributor plate on the feed gas inlet further reduces the possibility of impingement and subsequent channeling within the bed.[2]

Figure 3 - Adsorber Vessel Internals - Typical Arrangement using Bed Support Plates



The flow of gas through the adsorbing/regenerating beds is directed by orbit valves, controlled by the plant distributed control system (DCS). Each vessel has four associated valves to switch between the adsorption and regeneration phases of a cycle. As there is only a single valve between the hot regeneration loop and cold product gas, it is important that the chosen valves are capable of operating at high temperatures and providing complete seals. Any leakage in the system will pass from the regeneration side to the adsorption side, because of the marginally higher operating pressure in the regeneration system.

Such an event does not constitute an operational hazard but can, under certain circumstances; result in an increase in product gas water or hydrocarbon content.

<u>Adsorbent life time:</u>

The Rosetta adsorption unit is designed for three years bed life time. This life time may be affected by operating conditions, which may accelerate bed aging or might extend the bed life time.

<u>Adsorption of Water and Hydrocarbons – Adsorption cycle</u>

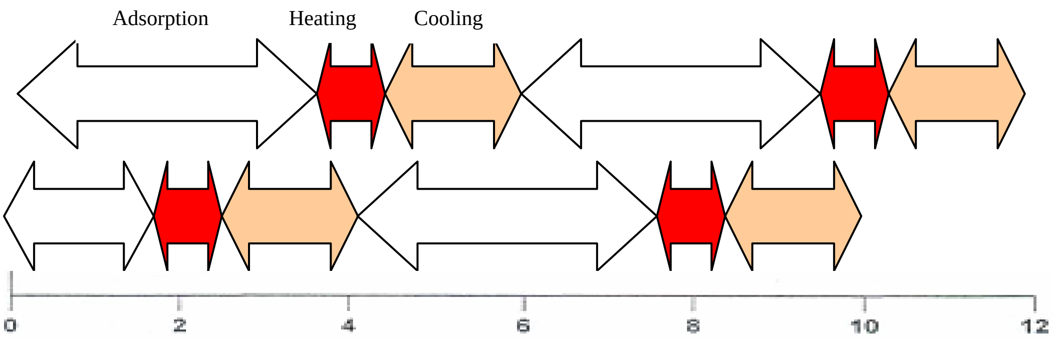
Each Adsorption unit consists of two adsorption towers, with a process capacity of 302 MMscfd /each of feed gas. The inlet gas feed flows to the online bed, which adsorbs the water and heavy hydrocarbons from the feed gas. During this time, the offline or regenerating bed is regenerated with heated feed gas to desorb the components from the bed, ready for re-use.

The sequencing of the beds is illustrated below:

Sequence of a 2 Bed Adsorption System

Tower A

Tower B



Cycle Time (hrs)

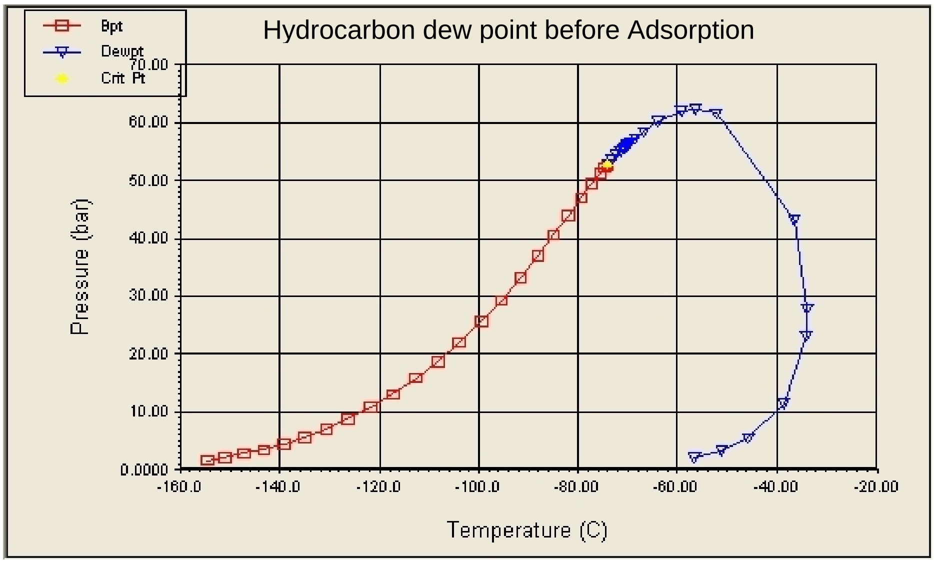
Product Gas Dew point Measurement & Control

The Adsorption unit is designed to achieve the following gas dewpoints:

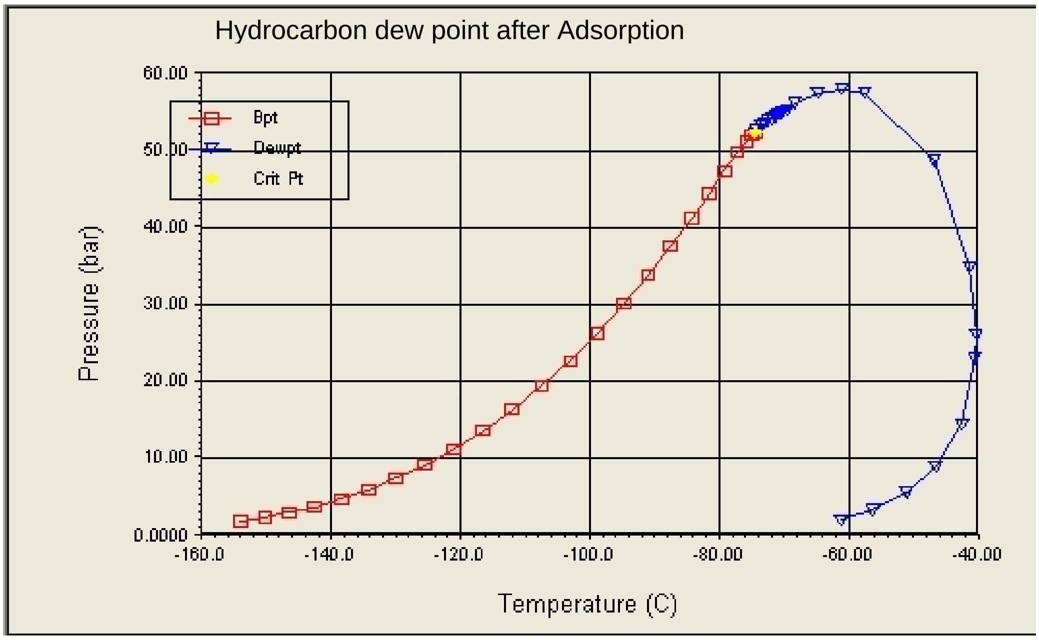
1. Hydrocarbon dewpoint: +5 °C at pressures below 68.7 barg
2. Water dewpoint: 0 °C at 68.7 barg

Given that Silica gel has a stronger affinity for water than for hydrocarbons, during the adsorption cycle, the beds preferentially adsorb water over hydrocarbons and the continuing adsorption of water would eventually start to displace previously adsorbed heavier hydrocarbons. Essentially therefore, the plant will always meet the water dew point and hence the plant is controlled on the hydrocarbon dew point of the product gas.

The following graphs illustrate the gas phase envelopes before (Figure 4) and after the Adsorption unit(Figure 5), the hydrocarbon dew point during drying cycle(Figure 6) and the C6+ breakthrough(Figure 7).[3]



Feed gas phase envelope Figure 4



Sales gas phase envelope Figure 5

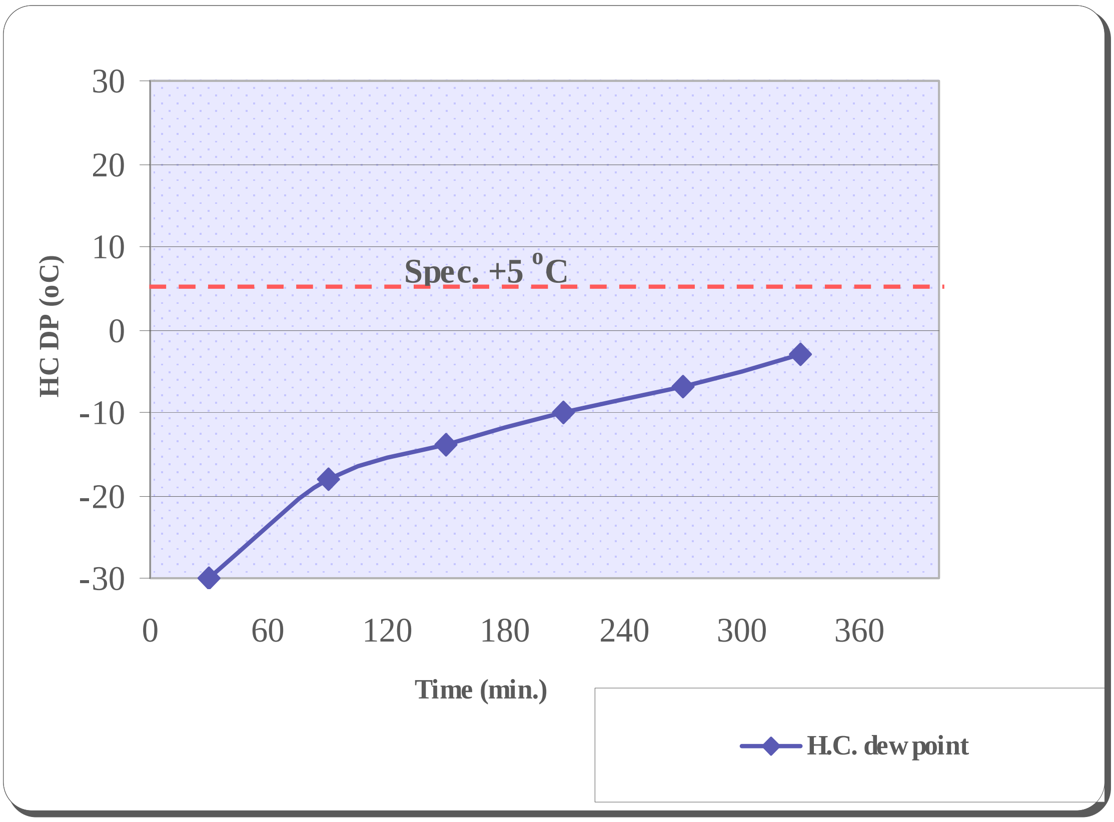


Figure 6 , illustrates the Hydrocarbon dew point through the Adsorption cycle

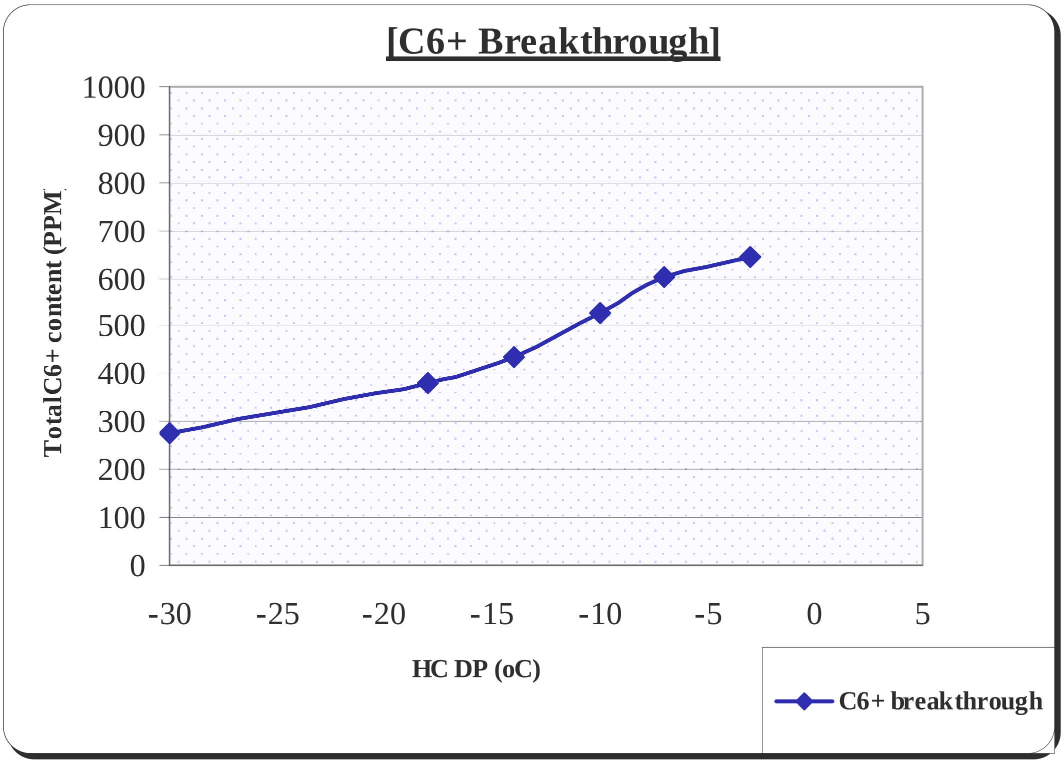


Figure 7, illustrates the C6+ breakthrough at the Adsorption cycle

Rosetta gas plant TSA unit

Hydrocarbon gas from the Inlet Separator is saturated with water and heavy hydrocarbons. Prior to the gas being exported from the plant it is necessary to dry the gas stream to an acceptable standard. To achieve this, the gas is dried in a dual Adsorber drying system using a solid desiccant. The system is equipped with a drier regeneration package, which allows one drying unit to be regenerated whilst the other is on line.

Description

Equipment List

EQUIPMENT No	SERVICE
Hydrocarbon Dew Point Package	
FL-2521	Feed Gas Filter Coalescer
V-2521/2	Adsorber Towers
FL-2522 A/B	Treated Gas Filter
Regeneration Equipment	
H-2521	Regeneration Gas Heater
A-2521	Regeneration Gas Cooler
E-2521	Regeneration Gas Sub-Cooler
V-2525	Regeneration Gas KO Drum
V-2526	Regeneration Gas KO Drain Drum

Process Description

The gas stream from the Inlet Separator V-2023 is fed to the Feed Gas Filter Coalescer FL-2521. The purpose of this filter is to remove any entrained liquid droplets from the feed gas stream. This is necessary, as liquids in the feed are likely to cause damage to the adsorbent.

Two Adsorption Towers, V-2521 & 2, are provided with one treating the process gas while the other is being regenerated. The process gas is fed to the online tower where it flows downwards through the adsorption tower which is packed with two grades of silica gel. The silica gel preferentially adsorbs water and heavy hydrocarbons.

After regeneration the silica gel is already saturated with C_5 hydrocarbons as it comes on stream. As the Adsorption process advances these are displaced by heavier hydrocarbons, which move down the bed.

Any hydrocarbons lighter than C_5 essentially pass straight through the bed and by retaining the heavier hydrocarbons the adsorber achieves the required hydrocarbon dew point of 5^oC. The bulk of the water is retained on the top layer of the silica gel.

Regeneration is performed using heated fuel gas at approximately 300^oC from the Regeneration Heater H-2521. The hot regeneration gas passes through the tower, which is being regenerated, in the same direction as the normal flow and dries the bed. As regeneration proceeds the heat passes downwards through the bed, driving the hydrocarbons and water off the silica gel.

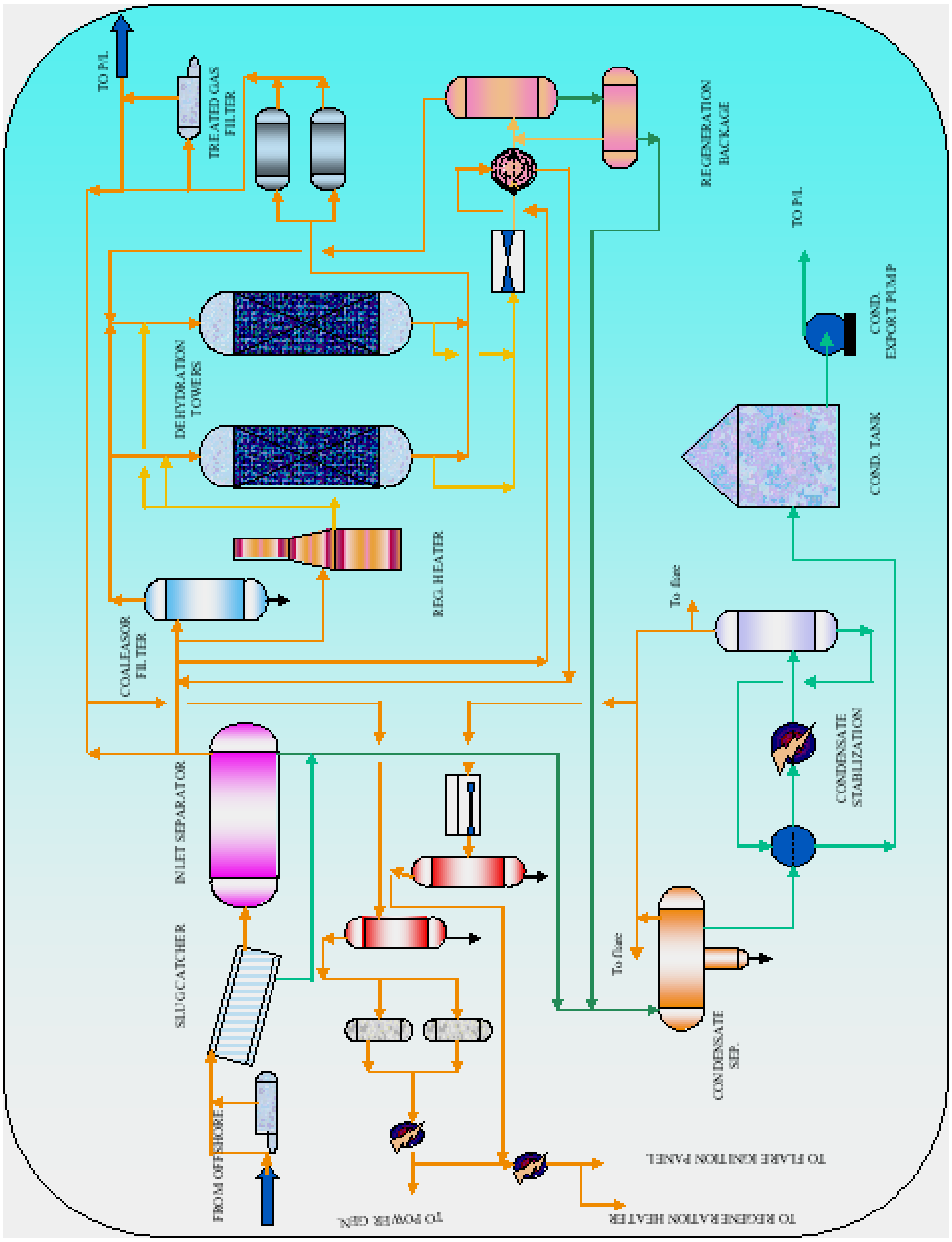
The hot regeneration gas from the bed is cooled by air, provided by three variable pitch fans, in the Regeneration Gas Cooler A-2521 to 50^oC. It is then further cooled against feed gas from the Inlet Separator V-2023, in the Regeneration Gas Sub-cooler E-2521 to approximately 28^oC.

Halfway through the regeneration, the system is switched to cooling. The Regeneration Heater firing is stopped and cold gas from the filter/coalescer flows through the bed. The Heat Pulse continues to move down the bed with the bed behind the pulse now being cooled, and loaded with hydrocarbons. Regeneration is completed when the Heat Pulse leaves the bottom of the bed indicated by a bed outlet temperature rise.

Condensed liquids from the regeneration gas stream are removed in the Regeneration Gas KO Drum, V-2525, and the cooled regeneration gas recombined with the feed to the online tower. The condensed liquids then pass to the Regeneration Gas KO Drain drum V-2526, where any gas passes to the

Regeneration Gas KO Drum. The condensed liquids pass to the Condensate Separator V-2024.

The duty of the towers is controlled automatically from the DCS on a timed sequence, typically between two and three hours. The regeneration period is the same as that of the duty period, with the duration of the heating and cooling cycles being equal. After passing through the adsorption system the conditioned gas stream passes through the Treated Gas Filter, FL-2522 A/B, which remove any dust carried over from the Silica Gel bed, before passing through the Gas Metering Package, X-2721.[1]



Conclusion

The adsorption process using the new silica gel type in Rosetta gas field proved that it has

- High performance even with high flow rates

(The Rosetta plant is designed for 302MMSCFD and has been tested up to 380 MMSCFD)

- High reliability and high efficiency.
- Low operating cost.

References:

1. Rosetta gas field design basis (Enppi)
2. Evaluation study for Rosetta gas field hydrocarbon dew pointing unit (Enppi)
3. Rosetta gas field TSA unit performance (Advantica)
4. Rosetta gas field high flow rate trial (Rashpetco operations)