# Natural Gas Unit Operations Engineering

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**IN** a previous article published in JURUTERA back in 2007, the author had provided the beginning for the thought processes involved in designing a gas processing facility. The article started off with an introduction to pertinent gas properties, and then moved on to the overall concepts that had to be considered when putting together the specifications and concept selection of the facility. Then some insight into what goes on in the upfront modelling process and the tools available for use were provided.

This article continues on the same topic. It will focus more on describing at a high level the functions of various unit operations in the facility, and what to think about when putting the whole scheme together. As before, the thinking that goes into the process is provided from a chemical engineering standpoint, which corresponds to the designation of 'process engineer' in the oil, gas and petrochemical industry.

## SEPARATION

Separation, in its basic form, is to physically separate the different phases in a multi-phase process stream. At the high school level, the phases of matter are solid, gas and liquid (and plasma for those who attended the advanced courses.) In the industry, we talk about two phases (gas/liquid and liquid/liquid) and three phases (gas, liquid hydrocarbons and liquid water) separation, depending on the demands of the process. The illustration in Figure 1 relates to the following text:

i) If the intent is to separate out liquids, to either prevent damage to the equipment that will process the gas or degrade the efficiency of such equipment, then two phase - separation might be sufficient. Examples of such a separation may be upstream of a compressor, or upstream of a glycol dehydration contact tower.

ii) Three-phase separation might be required if the liquid phase has to be treated to meet certain constraints. For example, the water content in condensate may have to be removed if a downstream process has a maximum allowable limit, or if the condensate is to be sent directly from separation to a customer who requires it to be below a certain level. The same thought process might apply if the hydrocarbon content of produced water needs to be reduced to regulatory or acceptable levels prior to disposal.

Note that to reduce the amount of water vapour in the gas phase, physical separation is not a practical process. Other means are required to achieve this task. The most common form of equipment used in separation is a vessel. It will have the following features and is illustrated by Figure 2:

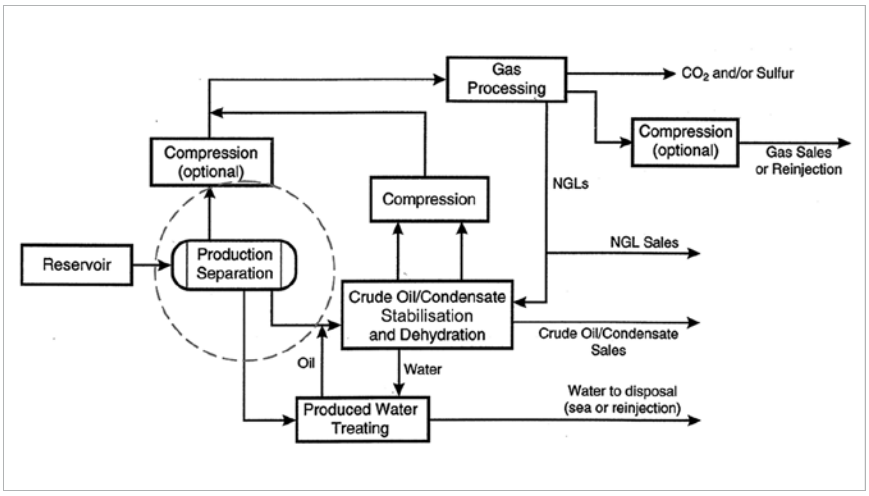


*Figure 1: Block diagram of gas processing*

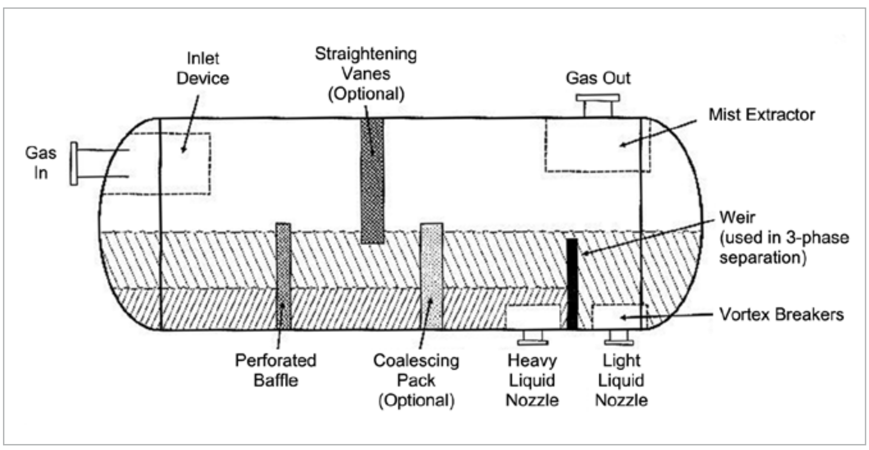


*Figure 2: Separation vessel*

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i) Initial bulk separation is where the bulk of gas/liquid separation occurs.
ii) Compartments where the liquid phases are allowed to be relatively still to allow for further separation. Sufficient time is given to allow gas bubbles to rise to the top of the liquid space, condensate droplets in water to rise to the bottom of the condensate/water interface, or water droplets in condensate to drop to the same interface.

Various equations that assist in the design of separators are available in the industry. These equations attempt to provide minimum sizing dimensions using physical first principles that are functions of droplet size, settling velocity and residence time. These equations are then tuned based on the separation requirements and operating experience to determine vessel sizes. However, the dimensions that result from such equations may be reduced if the efficiency of the separation process is increased. This can be achieved via two approaches:

i) Take the normal separator design and add internals to improve the quality of the separation. This might be in the form of devices to improve gas and liquid flow (*e.g.* Schoepentoeter to improve inlet flow, or straightening vanes to make the best use of the separator width) as illustrated in Figure 3, or devices that assist in increasing entrained liquid droplets so as to improve the process of separation by gravity (coalescer devices.)
ii) Separation of phases using forces other than gravity. An example as illustrated in Figure 4 is to use centripetal force for either gas-liquid separation, or the separation of different liquid phases. These designs are more vendor dependent, as the sizing equations tend to be proprietary, with the objective of delivering a more compact device of given process requirement, which is a plus on both technical and commercial basis.

The following items should be considered when designing a separation system:

i) The design flow rates throughout the life of the facility. There are different demands on the separation vessel during the stages of initial facility start up, production, rejuvenation and tail end. These different periods would entail different flow rates of the various phases. The vessel should be designed to either cater for all conditions, or designed in such a way that the vessel can be later adopted to suit the production conditions.
ii) Non-steady conditions: Upstream facilities generally do not have steady process conditions at the inlet of the facility. An example of such an unsteady flow is the phenomena of slugging. This is where liquid and gas may come in 'batches' to the facility due to the dynamic interplay between the gas and liquid phases and the physical layout of the pipeline. The flow rates of phases will fluctuate around an average value. The profile of these fluctuations can be predicted using various modelling software. The production separator, being the first unit operation that faces these conditions, should be designed to handle this phenomenon.
iii) Non-steady conditions: Another phenomenon that might need to be catered for is pigging. This occurs when a pig is sent down the pipeline upstream of the facility. Typically, liquid builds up ahead of the pig, and acts as a large slug.

Solids handling: a full wellstream might not only consist of gas and liquid, but might contain a significant amount of solids, usually in the form of sand. The sand might be the cause of erosion of piping, heavy wear of valve and pump internals. Therefore, there is a good reason to remove sand from the process at the separation vessel, which is usually the first unit operation. Such solid handling methods could be an online continuous removal system, transportation of solids to a process downstream of the vessel, or something as basic as a scheduled shutdown with big, burly men, shovels and a lot of bags.

The type of equipment used to measure the process conditions. Some fluids are dirty and quickly block the small nozzles used by the displacer type level measurement devices. In this case, a more suitable device might be a capillary type device, or one that uses radar to directly detect the liquid surface. Note that this plethora of choices does not apply to the measurement of gas properties.

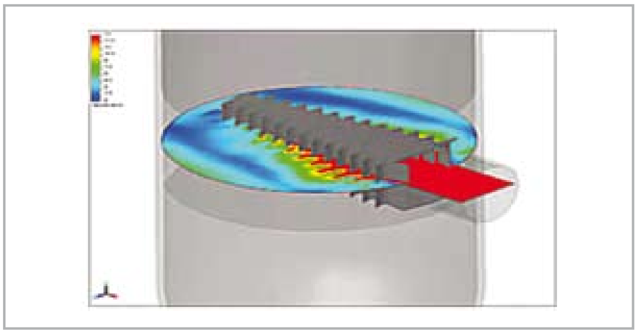

*Figure 3: Flow enhancement device*

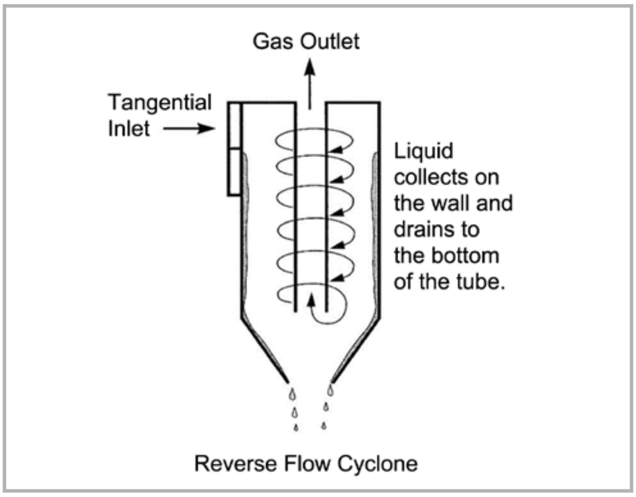


*Figure 4: Separation via centripetal force*

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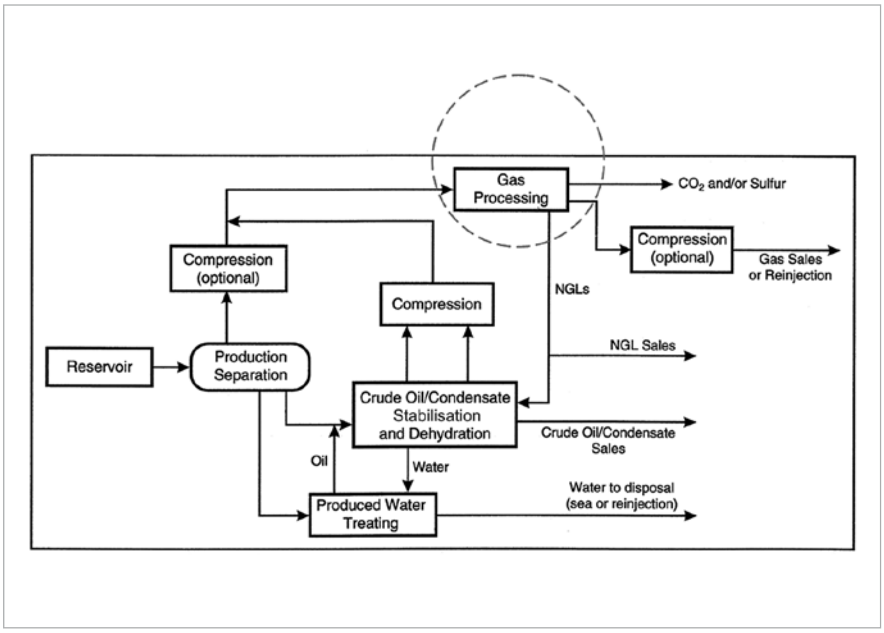


*Figure 5: Dehydration of the gas stream*

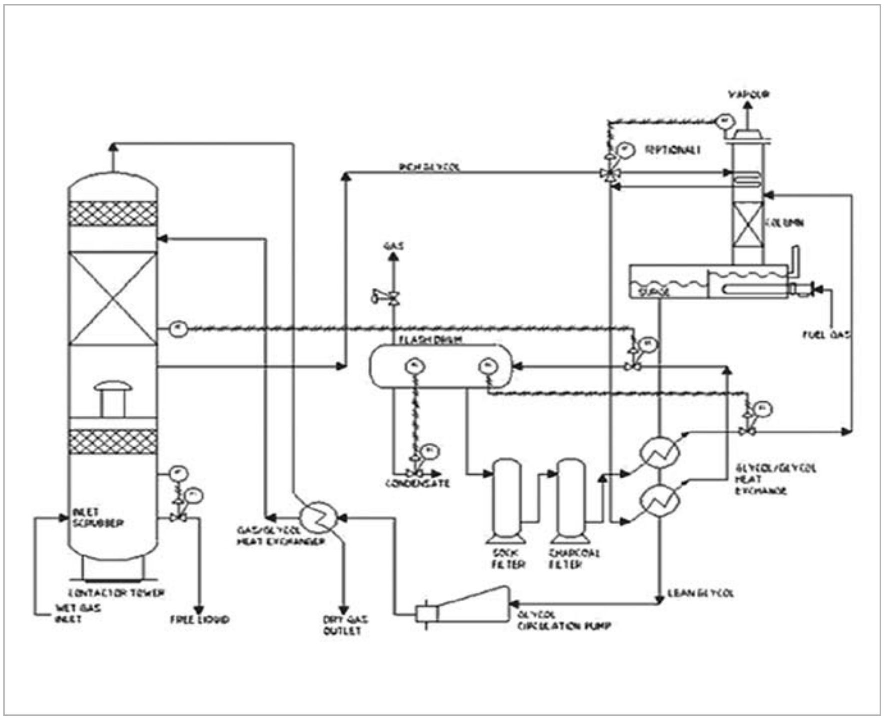


*Figure 6: Glycol contactor and regeneration system*

## DEHYDRATION

Dehydration of the gas stream means to remove water vapour in the gas to meet the maximum water content. Note that this is different from the removal of water in a liquid state. The reasons for drying a gas stream have been mentioned in the previous article.

The most common method of dehydrating a gas stream is using glycol, an organic liquid that has an affinity for water vapour. Glycol, which has low water content (dry glycol), is put into contact with a gas stream. The water vapour is then absorbed by the glycol and removed from the process stream (wet glycol.)

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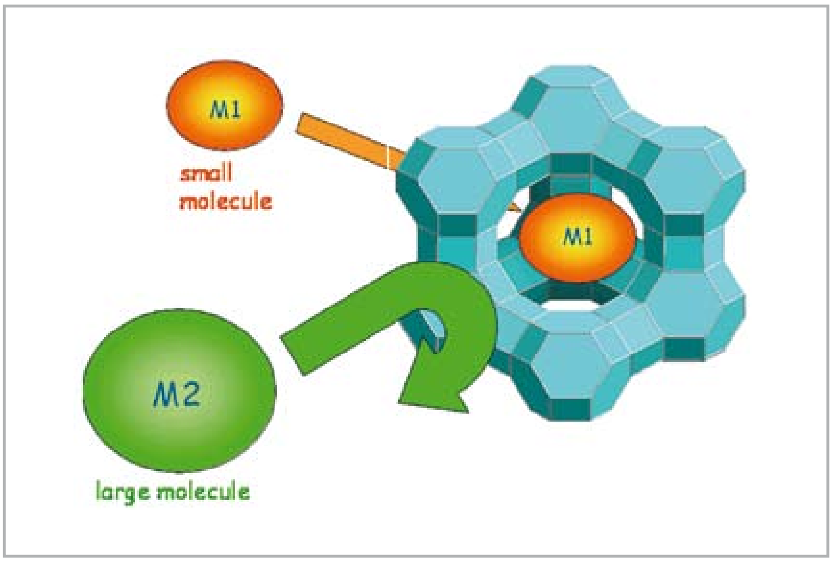


*Figure 7: Molecular Sieve*

The glycol-gas interface happens inside a contactor, which has internals designed to maximise the amount of surface area between the two phases to allow for the fastest amount of mass transfer between the two. A lot of computation power and effort has been put into the design of the internals, matching available information and construction capabilities. The earliest method of creating the largest amount of surface area per volume of contactor was using oddly shaped discrete objects and poured inside a container vessel.

An obvious advantage is that the packing was simple to install, and results could be analysed and predicted with the technologies of the day. The disadvantage of this system was that it was not optimised. Channelling (preferential, non-distributed flow) of the gas and liquid could occur, thus reducing the contact area per contactor volume, and requiring additional contactor volume to compensate for this effect.

With better tools and understanding of the process, structured packing was more likely to be used and installed. This packing comes prefabricated, and bears some resemblance to a Weetabix wafer. These components are systematically installed, and provide a larger interface area per volume available, reducing the amount of volume required to meet the necessary phase contact area. Efficient designs are under the purview of specialist companies.

However, the purchasing engineer needs to provide correct data to the vendor, for example, expected flow rates, available utilities and potentially provide corrective systems around the contactor (Does one need a recovery vessel downstream for glycol that is entrained in the gas stream? This point has to be confirmed.)

Wet glycol is regenerated by heating the glycol and evaporating the water in a reboiler. The temperature chosen has to be as high as possible such that the maximum water boil off rate may be achieved without decomposing the glycol.

Although functionally simple, various optimisation steps have been incorporated into the design. For example, the relatively cold and rich glycol stream from the process is used as a reflux coil in the glycol reboiler. This has the effect of recovering heat from the water boiled off the glycol. Heat exchangers provide the further recovery of heat. Vessels as illustrated in Figure 6 are installed to recover any hydrocarbons that may have been entrained in the glycol. As contaminants affect the efficiency of the system, systems have to be installed to remove them (via filters) or reduce the effects (via neutralisers.)

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Another method of drying gas would be through the use of solids. The solid used has a structure such that water molecules are trapped and held within the solid while gas molecules are not. Hence, the solid works as a desiccant. An example, as illustrated in Figure 7, of such a material is the molecular sieve.

One advantage of using such materials is that a much lower dew point can be achieved, between -40°C to -50°C. Another is that the material may be regenerated using either a heat source (heated dried gas) or by lowering the system pressure. This eliminates the need for a reboiler and its various accessories. A common example where solid dehydration is used is to dry out air for use in pneumatic instrumentation.

A third advantage is that dehydration by solids can remove more than just water molecules. This conditions the gas for further processing downstream. For example, molecular sieves might remove $H_2S$ from a gas stream in addition to water, sweetening the gas in preparation for further processing downstream.

How dry does the gas need to be? This is where engineering number crunching and a layman's intuition come together. The dryer the gas needs to be, the lower the water content of the drying medium or, in countercurrent systems, the lower the water content of the wet glycol exiting the contactor.

This, in turn, affects the design of the regeneration system. One could lower the exit water content of the wet glycol either by reducing the moisture content of the dry glycol entering the contactor, or by increasing the glycol flow rate. This eventually turns out to be an economic decision where operating costs versus capital costs are considered.

Another consideration might be two different processes in series to achieve the required effect, for example, using glycol to perform bulk dehydration, and then using solid absorption to meet the required dewpoint.

## SUMMARY

The preceding text discusses two unit operations that would typically be found in an upstream gas processing plant. It is hoped that the reader will appreciate the high level thought processes invoked in a design, and provide prompts when considering other designs. ■

*Note: The author intends to continue this series with discussions of other unit operations.*