

# NATURAL GAS PROCESSING

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## Contents

1. Introduction
  2. Description of a natural gas processing plant: an overview
  3. Sweetening of sour natural gas
    - 3.1. Overview and Methods Used
    - 3.2. Chemi-sorption Sweetening Processes (Amines)
      - 3.2.1. Description of Equipment and Unit Operations
      - 3.2.2. Design and Operating Features
    - 3.3. Physical Methods
      - 3.3.1. Physical Solvents
      - 3.3.2. Molecular Sieves
    - 3.4. Other Methods
    - 3.5. Conversion of H<sub>2</sub>S Gas to Elementary Sulfur(Claus Process)
  4. Gas dehydration
    - 4.1. Fundamentals
    - 4.2. Predictions of Conditions Leading to Hydrate Formation
    - 4.3. Dehydration Processes using Liquids (by Absorption)
    - 4.4. Dehydration Processes using Solid Desiccants (by Adsorption)
    - 4.5. Dehydration by Condensation (Cooling)
    - 4.6. Chemicals for Hydrates Inhibition
    - 4.7. Comparison of Dehydration Methods
  5. Recovery and extraction of NGL constituents (C<sub>2plus</sub>)
    - 5.1. Introduction
    - 5.2. The Cryogenic Expansion Process
    - 5.3. The Absorption Process
  6. Fractionation of NGL constituents
  7. Conclusion
- Glossary  
Bibliography  
Biographical Sketch

## Summary

Natural gas processing consists of separating first, all impurities found including acid gases, water vapor, and inert gases. This stage is called Gas Treatment. Sweetening of sour natural gas is the initial purification step which takes care of the removal of acid gases (H<sub>2</sub>S and CO<sub>2</sub>). Amine treatment, physical methods and others are discussed. Gas dehydration is carried out next using glycols (TEG) or solid desiccants for gas

dehydration. Conditions leading to hydrates formation are highlighted. Chemicals for hydrate inhibition are recommended.

Gas Processing is the second and most important stage is concerned with the recovery and extraction of NGL from natural gas, followed by fractionation to separate components.

Modern gas processing plants use cryogenic low temperature distillation process based on the expansion of the gas through a turbo-expander.

A fractionation column, called demethanizer follows. Methane, the residue gas and NGL are the products from this column. Fractionation of NGL requires the use of a number of distillation columns for the separation to the desired components and/or products.

## 1. Introduction

There are primarily three sources for “raw” natural gas. These are recognized as:

1. Crude oil wells
2. Gas wells
3. Condensate wells

Natural gas that comes along with crude oil is normally known as associated gas. It can exist separately from crude oil, forming what is known as a gas cap or dissolved in the crude oil.

Natural gas from gas wells and from condensate wells-in which there is little or no oil-is termed, on the other hand non-associated or free gas.

Gas wells differ from condensate wells, since the former type produces raw natural gas only, while the latter one produces natural gas along with very light liquid hydrocarbon known as natural gasoline because it has a high octane number.

One may ask what is natural gas? Basically, raw natural gas consists of methane along with varying amounts of:

- Heavier gaseous hydrocarbons
- Acid gases that may include hydrogen sulfide, carbon dioxide and others
- Other gaseous components, such as nitrogen and helium
- Water that may be found in both liquid form and as water vapor
- Liquid hydrocarbons

Very small amounts of mercury may be found in elementary form in some locations.

The schematic diagram shown in Figure1 illustrates how natural gas produced by gas-oil separation (associated natural gas), may contain heavier hydrocarbons.

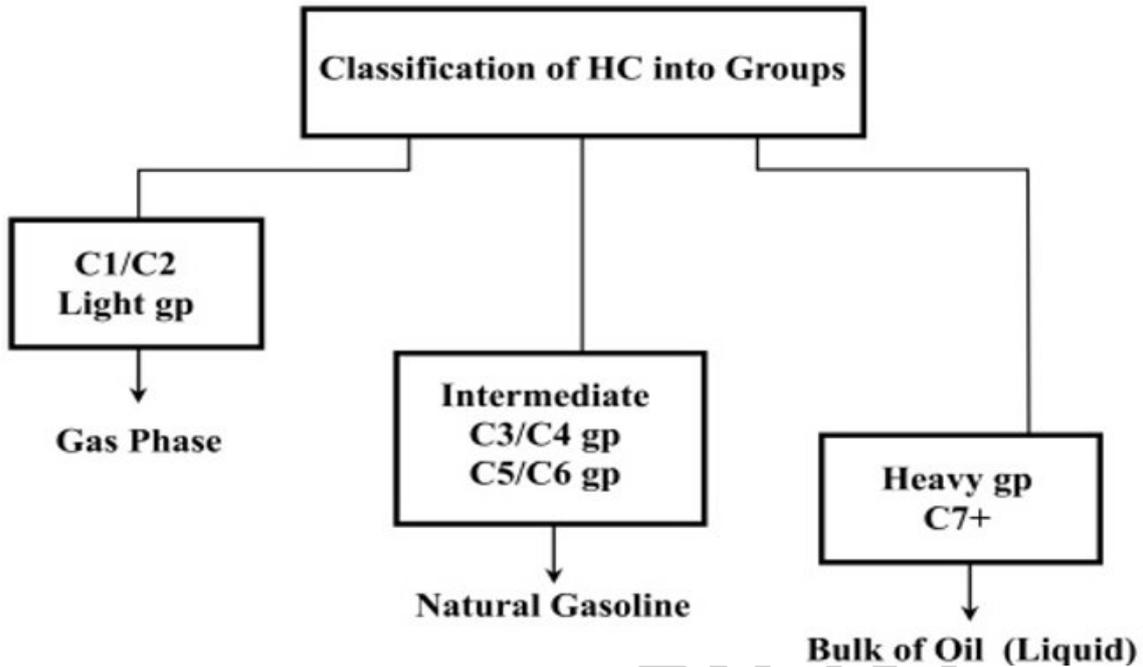


Figure 1. Classification of Hydrocarbons Found in Wellhead Fluids

The processing of natural gas in general, both associated gas (separated at the GOSP as presented in the theme entitled Surface Petroleum Operations), or free gas, implies the removal of several undesirable components or impurities, before the gas can be utilized as a fuel or as a feed stock for petrochemical industry.

It should be purified to meet the quality standards specified by the major pipeline transmission and distribution companies to produce what is known as “pipeline quality” dry natural gas. Gas field processing in general is carried out for two main purposes:

- The necessity to remove impurities from the gas
- The desirability to increase liquid recovery above that obtained by conventional gas processing.

## 2. Description of a Natural Gas Processing System: An Overview

Natural gas processing and the removal of various components from it tend to involve the most complex and expensive processes. All of the H<sub>2</sub>S and most of the water vapor, CO<sub>2</sub>, and N<sub>2</sub> must be removed first.

The separation of the hydrocarbons, known as NGL (C<sub>2</sub> plus) is carried out next producing methane as the sole product commercially marketed as natural gas.

A system for natural gas processing my basically involve two main stages, apart from the oil and gas condensate removal step (see Figure 2):

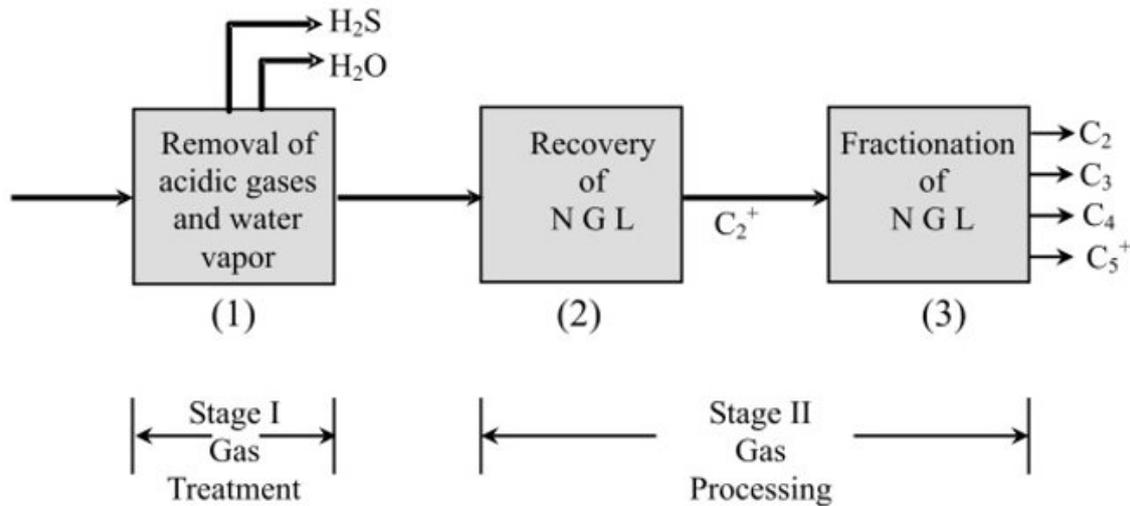


Figure 2. Natural Gas Processing System

- (a) Stage I and is known as gas treatment or gas conditioning
- (b) Stage II and is known as gas processing

The gas treatment operations carried out in stage I include the removal of gas contaminants, in particular H<sub>2</sub>S (gas sweetening) followed by the separation of water vapor (dehydration). On the other hand, stage II, comprises two operations: NGL recovery and separation from the bulk of gas and its subsequent fractionation into the desired products. A sum up of these operations is given as follows:

- Gas sweetening
- Gas dehydration
- Recovery and extraction of NGL (C<sub>2</sub> plus)
- Fractionation of NGL into individual products, which may include: ethane, propane, butane, isobutene, and natural gasoline.

The following are some of the most important parameters to be considered in the design of a system for natural gas processing:

1. Estimated gas reserve (both associated and free)
2. Gas flow rate and its composition
3. Market demand for both local export
4. Geographic locations and methods of shipping of finished products
5. Environmental factors
6. Risks imposed in implementing the project and evaluation of its economic feasibility

In general, the type of processing operations recommended for any specific plant, depend on the kind of gas under consideration along with the distribution of the hydrocarbons found in the gas. In particular the following factors are significant:

- The contents of heavier hydrocarbons

- The percentage of acid gases
- The presence of inert

Figure 3 illustrates some diversified processing operations that take place in the treatment of natural gas produced by different reservoir formations.

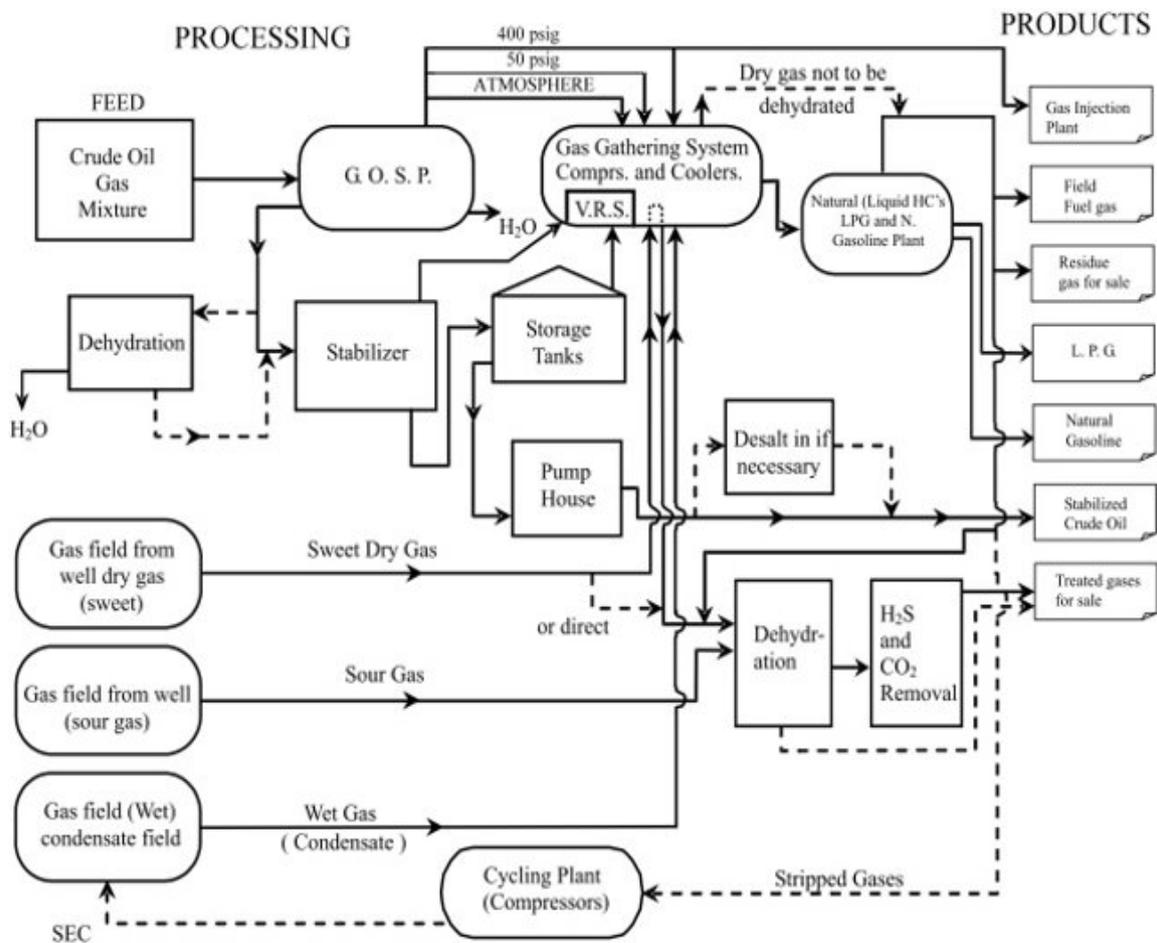


Figure 3. Schematic Presentation of Processing Operations

### 3. Sweetening of Sour Natural Gas

#### 3.1. Overview and Methods Used

When processing sour natural gas, the sweetening process almost always precedes dehydration and other gas plant processes carried out for the separation of NGL. Dehydration on the other hand, is usually required before the gas can be sold for pipeline marketing. At the same time, it is a necessary step in the recovery of NGL from natural gas as will be explained later on.

As stated earlier, natural gas contains some impurities such as H<sub>2</sub>S, CO<sub>2</sub>, water vapor, and other sulfur compounds. Natural gas that contains more than 5.7 milligrams of H<sub>2</sub>S per one cubic meter of natural gas is "sour". However, if it contains only CO<sub>2</sub> and no

other sulfur compounds, it is called “sweet” gas. It is usually desirable to remove both H<sub>2</sub>S and CO<sub>2</sub> to prevent corrosion problems in the first place and to increase the heating value of the natural gas by eliminating CO<sub>2</sub>. In this regard, sweetening of natural gas is a vital step for three main reasons:

- Health hazards: at 500 ppm of H<sub>2</sub>S, breathing problems are observed and death can be expected in minutes.
- Sales contracts: no more than 0.25 grain of H<sub>2</sub>S per 100 scf of gas.
- The main benefit obtained from the removal of both of these acid gases from a pipeline stream is to minimize the corrosion effects. In addition, the recovery of sulfur represents a commercial incentive.

The methods used for natural gas sweetening can be classified under three categories:

1. Reactive chemical solvents
2. Physical methods
3. Other methods

Detailed classification of the individual processes is given in Figure 4 and Figure 5.

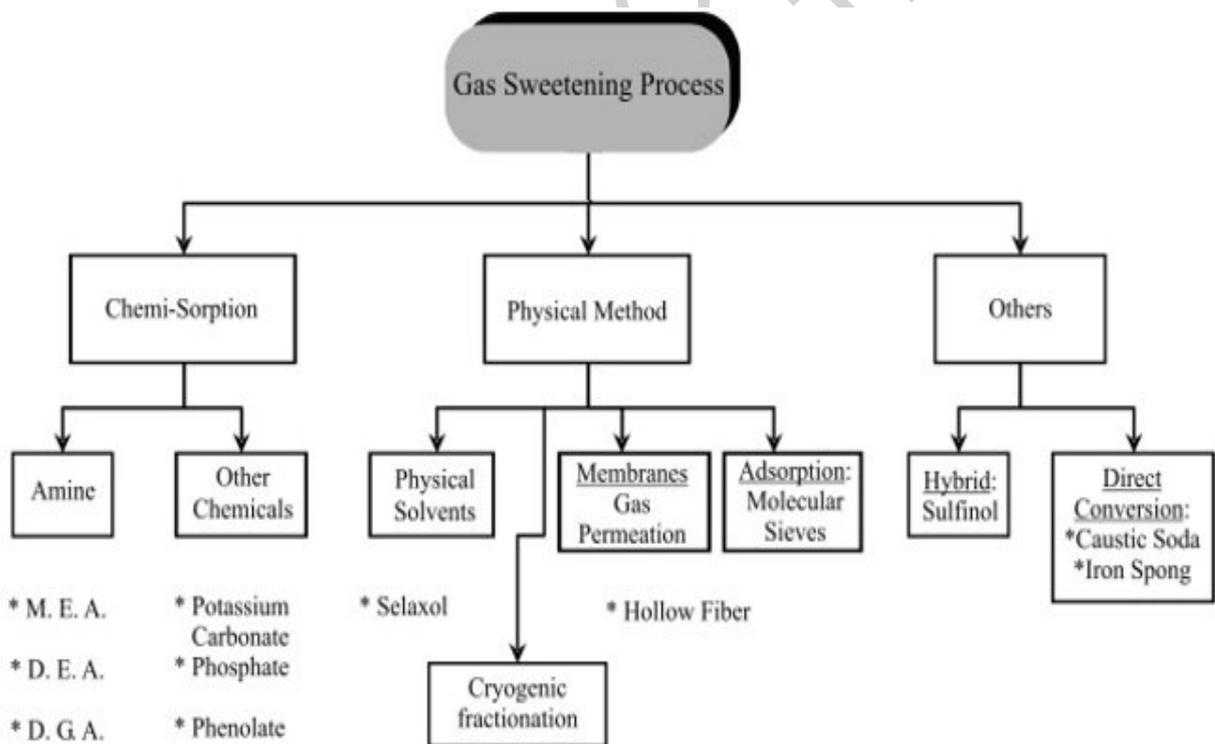


Figure 4. Classification of Gas Sweetening Processes

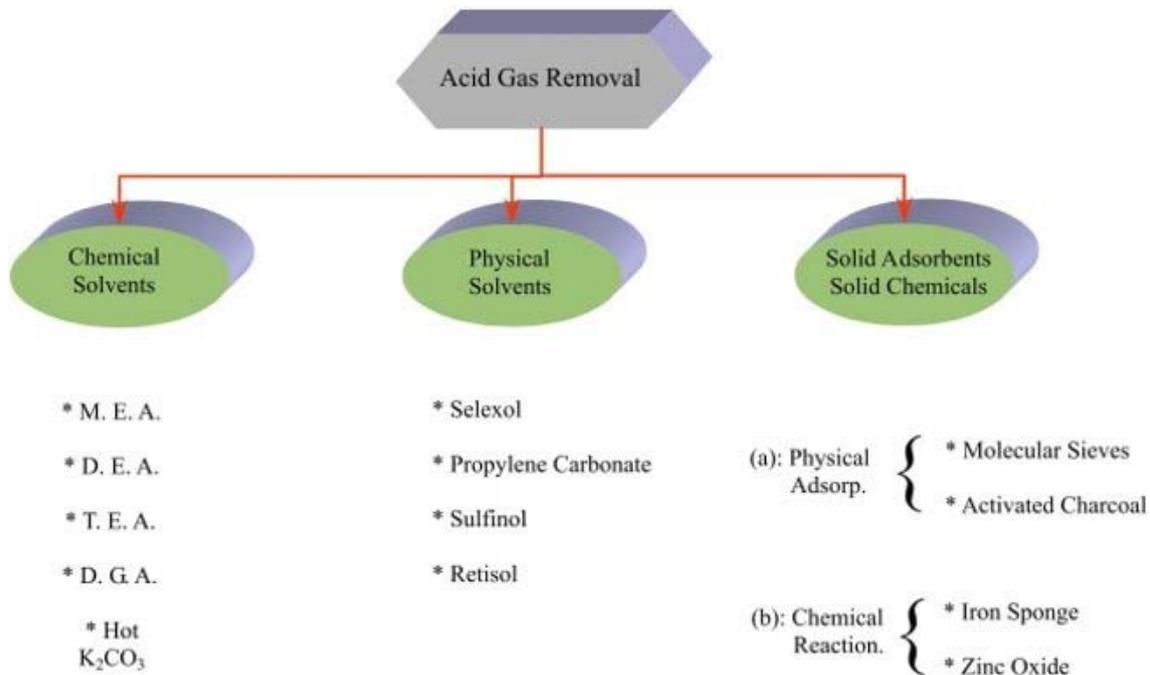


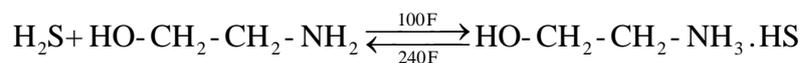
Figure 5. Other option of Classification of Gas Sweetening Processes

### 3.2. Chemi-sorption Sweetening Processes (Amines)

These processes use an aqueous solution of a weak base in order to react chemically along with absorption of the acid gases (H<sub>2</sub>S or CO<sub>2</sub>) to be removed from the natural gas. Absorption is attributed to the rate of mass transfer driven by the difference in partial pressure between the bulk of gas and the liquid. Reactions are identified as chemical-absorption, or chemi-sorption. They are reversed by the effect of temperature or pressure, which results in regeneration of the solvent used.

The common treating solutions are aqueous solutions of the ethanol amines: mono-ethanol amine (MEA), di-ethanol amine (DEA), tri-ethanol amine (TEA), or di-glycol amines (DGA).

The amine sweetening process is schematically outlined in Figure 6. It consists basically of contactor and a regenerator, where reaction occurs at 100 degree F, while regeneration takes place at 240 degree F:



Reaction could be applied to CO<sub>2</sub> as well. The ethanol-amine processes are recommended when the partial pressure of the acid gas is low/and or low levels of acid gas are desired in the residue gas. If the quantity of acid gas is large, hot potassium carbonate followed by amine treatment may be justified.

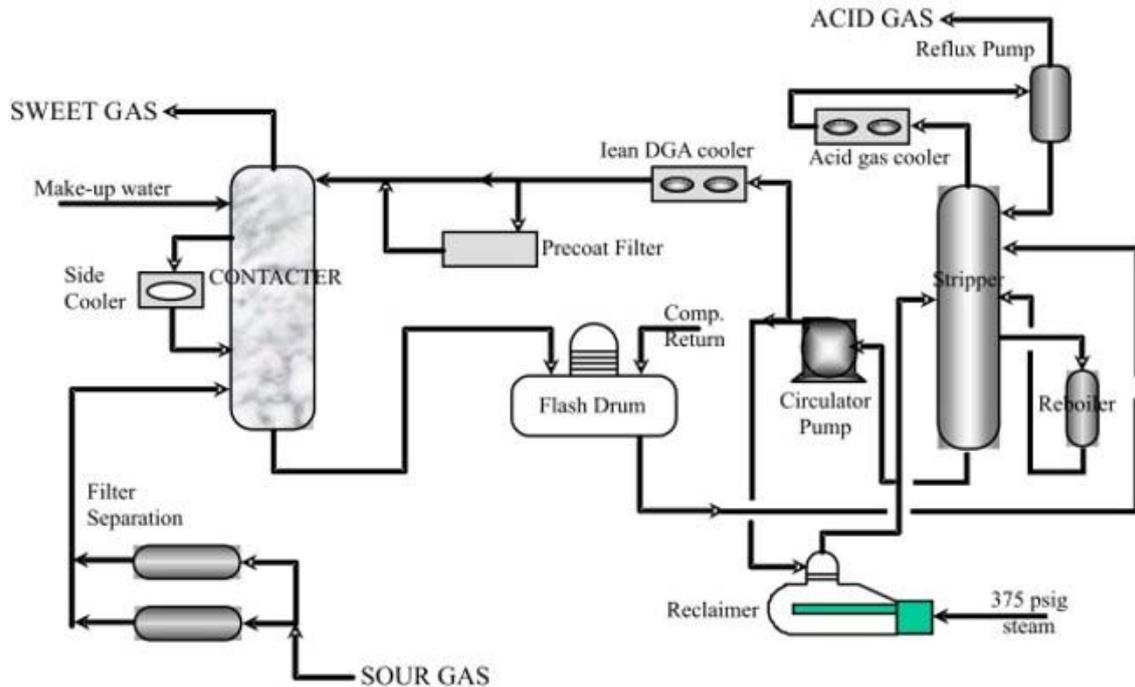


Figure 6. The Amine Sweetening Process

### 3.2.1. Description of Equipment and Unit Operations

The main equipment comprises the following:

The Contactor It involves a mass transfer operation (gas/liquid) in which the sour gas flows into the bottom of the column (contactor) and moves upward countercurrent to the solvent (which is amine-solution).

Generally, the number of bubble trays used in the contactor is from **sixteen to twenty trays**. The diameter of column, on the other hand, depends on the gas volume and operating pressure.

Heat exchangers It provides heat transfer to the bottom of the absorber, where the temperature of the solution is raised to about 180 to 220 degree F.

Regenerator It involves a mass transfer operation (stripping), where the rich amine flows into the regenerator stripping column, near the top, flows downward by gravity contacting the hot gases from the re-boiler. Acid gases are removed from solution, while lean amine is cooled first, then re-circulated back to the absorber.

Other equipment and Control This involves pumps and drivers, filters, and controls which include level controllers, temperature recorders and controllers, and pressure recorders.

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### **Biographical Sketch**

**Hussein K. Abdel-Aal** born in Egypt, 1935. He has B.S. Ch E, Alexandria University, 1956, M.S. & Ph.D. Ch E, Texas A. & M., TX, USA, 1962, 1965. Major field of study: chemical engineering.

He has more than 50 years of industrial experience, academic research and university teaching. He was a faculty member at NRC, Cairo, Egypt, 1965-70, Post-Doctoral fellow at UMIST, England, 1970-71, Visiting Prof., Texas A & M., College Station, TX 1980-81, Prof. at KFUPM, Dhahran, Saudi Arabia 1971-98. Currently, he is Emeritus Prof., NRC, Cairo, Egypt. He is the author of more than 50 publications and two books: *Petroleum Economics & Engineering*, Marcel Dekker Inc., New York 1992, *Petroleum & Gas Field Processing*, Marcel Dekker Inc., New York, 2003.

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