Mini Plant for LPG and Condensate Recovery from Small Amounts of Rich Natural Gas: Optimum Design of Dehydration Package

By

HAMDY REDA MOHAMED AHMED ELZOHAIRY

A Thesis Submitted to the
Faculty of Engineering at Cairo University
In Partial Fulfillment of the
Requirements for the Degree of
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in
PETROLEUM and NATURAL GAS TECHNOLOGY

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Flared Gas ; Mini-Plant ; NGL ; LPG ; HYSYS

Summary:

The present research work is a part of a research project that tends to study the technical and economical possibility of designing a mini-plant that can recover LPG and gas condensate from the small amounts of associated gas produced actually in the oil fields. This specific research will focus on thoroughly studying all dehydration techniques and comparing between them to determine the most suitable technique(s) for treating the small quantities of the flared rich associated gases. Complete design of dehydration package is created on the HYSYS simulation software and calculation sheets, including the operating conditions, power requirements, energy requirements, unit sizing, exact effluent conditions, specifications, and the unit capital and operating cost.

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To my parents and my wife, without whom none of my success would be possible

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Nomenclature

A	=	area, ft2
A°	=	Angstrom
B	=	constant for 4A Mole Sieve (Beads 1/8 " sieve) in Equation 4-1
C	=	constant for 4A Mole Sieve (Beads 1/8 " sieve) in Equation 4-1
Cp	=	heat capacity, Btu/(lb • °F)
Cg	=	gravity correction factor for water content
Cs	=	salinity correction factor for water content
Css	=	saturation correction factor for sieve
CT	=	temperature correction factor
CEPCI	=	Chemical Engineer Plant Cost Index
CO2	=	carbon dioxide
DEG	=	diethylene glycol
D	=	diameter, ft
d	=	depression of the water dew point or the gas hydrate Freezing point, °F
EOS	=	Equation of State
EC	=	Equipment Cost
f	=	Feed
G	=	mass velocity, lb /(ft2 • hr)
H	=	enthalpy, BTU/lb
H2O	=	water
H	=	hydrate
H2S	=	hydrogen sulfide
HC	=	hydrocarbon
ΔH	=	latent heat of vaporization, Btu/lb
I	=	inhibitor
i	=	inlet
Kvs	=	vapor/solid equilibrium
LPG	=	liquefied petroleum gas
L	=	length of packed bed, ft
Lg	=	glycol flow rate, U.S. gal./hr
LMTZ	=	length of packed bed mass transfer zone, ft
Ls	=	length of packed bed saturation zone, ft
L	=	lean inhibitor
l	=	liquid
m	=	mass flow rate, lb/hr
MTZ	=	mass transfer zone
MW	=	molecular weight
MWI	=	molecular weight of inhibitor
MEG	=	monoethylene glycol
NGL	=	Natural gas liquid.

N	=	number of theoretical stages
O	=	outlet
P	=	pressure, psia
ΔP	=	pressure drop, psi
q	=	actual gas flow rate, ft3/min
Q	=	heat duty, Btu/hr
Qc	=	reflux condensing heat duty, Btu/gal
Qhl	=	regeneration heat loss duty, Btu
Qr	=	total regeneration heat duty, Btu/gal
Qs	=	sensible heat, Btu/gal
Qsi	=	duty required to heat mole sieve to regeneration temperature, Btu
Qst	=	duty required to heat vessel and piping to regeneration temperature, Btu
Qtr	=	total regeneration heat duty, Btu
Qv	=	Vaporization of water heat duty, Btu/gal.
Qw	=	desorption of water heat duty, Btu
rg	=	regeneration
R	=	rich inhibitor
S	=	solid phase
Ss	=	amount molecular sieve req'd in saturation zone, lb
t	=	Thickness of the vessel wall, in.
T	=	temperature, °F
Trg	=	regeneration temperature, °F
TIC	=	total capital investment
TREG	=	Tetraethylene glycol
TEG	=	triethylene glycol
t'	=	total
v	=	vapor velocity, ft/sec
V	=	superficial vapor velocity, ft/min
v	=	vapor
w	=	water rate, lb/hr
W	=	water content of gas, lb/MMscf
Wbbl	=	water content of gas, bbl/MMSCF
Wr	=	water removed per cycle, lb
x	=	mole fraction in the liquid phase
X	=	mass fraction in the liquid phase
y	=	mole fraction in the gas phase
z	=	compressibility factor
γ	=	specific gravity
μ	=	viscosity, cp
ρ	=	density, lb/ft3

Abstract

Due to the presence of dispersed oil fields that produce small amounts of associated gas and as these fields are located far away from any existing processing plants it is not feasible to process these small gas quantities. In fact, it is not possible to build a separate gas plant for such small amounts of natural gas. On the other hand, it is neither possible to store these small amounts nor transport them to the nearest gas processing plant. Therefore, the only way for handling these small quantities of associated gas is to send them to the flare without any processing. Meanwhile, Egypt suffers a shortage in natural gas liquids (NGL) especially LPG for domestic use because of the limited gas amounts and the lean composition of most of the discoveries. Consequently, it has always been a challenge facing the Egyptian petroleum sector to fulfill the domestic needs, and the only available way was importing LPG; around 60 % of the total domestic consumption is now imported to bridge the gap between demand and supply in Egypt.

So the best way to try to solve this problem is to study the feasibility of design a mini-plant for separating the LPG components from small quantities of associated natural gas (1 and 3 MMSCFD) to recover LPG and condensate from the flared gases. The local manufacture to such mini plant, if is economically feasible, will help to increase national income, save hard currency and solve the environmental problems which result from the flared gas especially if the supervision team of the Mining Studies and Research Center (MSRC) succeed in designing a mini plant to convert these lean components of the flared gas (C_1, C_2) to a liquid product such as gasoline and solar.

The present study is a part of an integrated research work which aims to study the technical and economic feasibility of the local manufacture of a mini LPG separating plant which can be used for the recovery of NGL from small gas strands which are currently flared or used for power generation. Design objectives of the proposed NGL plant will include maximizing LPG production by using the most suitable available techniques, and a techno-economic study and an estimate of the IRR and payback period for the plant.

Normally any Natural Gas processing plant, rich natural gas, should include four main compartments these are Sweetening Unit, Dehydration Unit Chilling Train & Cooling System and The Fractionation System & Storage Tanks. The current research is concerned with conducting a detailed study of all dehydration techniques and comparing between them to determine the most suitable technique(s) for dehydrating the small quantities of the flared rich gases. Complete dehydration unit design is created on the HYSYS simulation software and calculation sheets, including the operating conditions, power requirements, energy requirements, unit sizing, the exact effluent condition, specifications, and the unit capital and operating cost.

The results attained from the present study revealed that among different dehydration techniques the adsorption is found to be the most suitable one by using 4A mole sieve dehydration types. The equipment for mole sieve dehydration unit (A4) includes inlet separator, dryer, regeneration gas cooler, regeneration gas heater, regeneration gas compressor and knock out drum. In Egypt, there are many small strands of associated gases (about 20 fields) that are either flared or used for electricity generation in site. The amount of flared gases in Egypt is around 110 MMSCF/D. the design of mini plant seems to be feasible from the economical point of view.

Chapter 1: Introduction

Flaring of associated gas is one of the most compatible energy and environmental issues facing the world today. Nearly 150 billion cubic meters of natural gas are flared annually around the word. This is considered a huge waste of natural resources and this shall lead to exerting 400 million metric tons of carbon dioxide tantamount global greenhouse gas emissions. [1]

Due to the presence of dispersed oil fields that produce small amounts of associated gas and as these fields are located far away from any existing processing plants it is not feasible to process these small gas quantities. In fact, it is not possible to build a separate gas plant for such small amounts of natural gas. On the other hand, it is neither possible to store these small amounts nor transport them to the nearest gas processing plant. Therefore, the only way for handling these small quantities of associated gas is to send them to the flare without any processing. Meanwhile, Egypt suffers a shortage in natural gas liquids (NGL) especially LPG for domestic use because of the limited gas amounts and the lean composition of most of the discoveries. Consequently, it has always been a challenge facing the Egyptian petroleum sector to fulfill the domestic needs, and the only available way was importing LPG; around 60 % of the total domestic consumption is now imported to bridge the gap between demand and supply in Egypt

In general, all these flared gases are classified as rich gas consisting of C1, C_2, C_3, C_4 & C_{5+} components. Literally speaking, these gases are rich with liquefied petroleum gases (LPG) which include C_3 & C_4 components as well as C_{5+} components known as the gas condensate. The LPG and the gas condensate are the valuable components of the gas while the mixture of C_1 & C_2 components is the lean gas, simply called the sales natural gas which is used as domestic fuels.

Nowadays there is a global trend which encourages dealing with wastes and side products as valuable starting materials and thus converting them to useful products. This point of view of waste management integrated systems, necessitated researchers to thoroughly investigate the opportunity to deal with these small amounts of flared natural gas as a valuable material rather than a waste simply flared or vented. Accordingly, this gas should be processed to remove the impurities and separate the heavier hydrocarbon liquids from the natural gas streams. These heavier hydrocarbon liquids, commonly referred to as natural gas liquids (NGLs), include ethane, propane, butanes, and natural gas (condensate). Recovery of NGL components from natural gas is not only required for hydrocarbon dew point control in the natural gas stream (to avoid the unsafe formation of a liquid phase during transportation), but also allows for a reliable energy source of further revenues. The NGLs have significantly greater value as a separate marketable product rather than as a part of the natural gas stream. Lighter NGL fractions, such as ethane, propane, and butane can be sold domestically or imported as fuel or feedstock to the refineries and petrochemical plants, while as the heavier portion, the condensate, can be used as gasoline-blending stock for enhancing the API value of crude oil.

Egypt suffers a shortage in natural gas liquids (NGL) especially LPG for domestic use because of the limited gas amounts and the lean composition of most discovered gases, so it has always been a challenge facing the Egyptian petroleum sector to fulfill the domestic needs and the only available way was importing LPG (around 60 % of the total domestic consumption is now imported) to close the gap in between demand and supply in Egypt.

From this perspective, the Faculty of Engineering at Cairo University represented in the Mining Studies and Research Center (MSRC), and Egyptian General Petroleum Cooperation Company (EGPC) and its affiliates companies, such as GASCO and PETROBEL showed much interest in investigating this problem in an attempt to find a reliable solution. The intended investigation would probably be carried out in two stages. The first stage concentrates on recovering the most valuable components in the associated gas (propane, butane and condensate) and the second stage is directed towards converting the lean gas after separating the valuable component from it to liquid (GTL technology).

The present thesis is a part of a research project that tends to study the technical and economical possibility of designing a mini-plant that can recover LPG and gas condensate from the small amounts of associated gas produced actually in the oil fields. This research work will focus on thoroughly studying all the dehydration techniques and comparing between them to determine the most suitable technique(s) for treating the small quantities of the flared rich associated gases.

This thesis consists of six chapters. The first chapter presents a general introduction which shows the importance of the current research. The second chapter covers the literature survey about the thesis topic. However; the third chapter advances the statement of problem, objective and the methodology that it used to achieve such objectives. The fourth chapter is prepared to deals with the implementation phase of the mentioned methodology. While, the fifth chapter exhibits the results and their interpretation and the sixth lists the conclusions and recommendations.

Chapter 2: Literature Review

2.1. Introduction

Natural gas is a mixture of gases containing primarily hydrocarbon gases. It is colorless and odorless in its pure form. It is the cleanest fossil fuel with the lowest carbon dioxide emissions. Natural gas is an important fuel source as well as a major feedstock for fertilizers and petrochemicals.

Natural gas pretreatment typically consists of gas sweetening and drying. Natural gas is dried in adsorbers or absorbs. Depending on the downstream processing steps and the concentration of the sour gas components, it may be necessary to remove H2S and CO2 from the natural gas. It should only minor amounts of sour gas be present.

Cryogenic processes are the most economical method for separating natural gas components. Undesired components are removed from natural gas to reduce transportation volumes and increase heating value.

NGL, LPG and condensate as well as the pure components methane, ethane, propane and butane often have higher sales values compared to the pipeline gas itself. Therefore, they are often extracted and fractionated in tailor made processing plants according to the specific requirements of the regional market and the customers. Due to their added value, heavier hydrocarbons are often extracted from natural gas and fractionated by using several tailor made processing steps.

LPG (Liquefied Petroleum Gas) is widely used as alternative fuel for cars, but is also suitable as a chemical feedstock. It consists of propane and butane (C3/C4).

This chapter aims at describing each of dehydration techniques used in natural gas processing plants in an attempt to prepare for introducing the selection criteria of each of the dehydration techniques.

The process of removing water from a natural gas although no condensed water is present in the system is known as dehydration. [2]

Dehydration is preferred, if economically and mechanically feasible, because it prevents water from condensing in the system. The presence of this water will be the source of many problems. These problems are:

1. Natural gas in the right conditions can combine with liquid or free water to form solid hydrates that can plug valves fittings or even pipelines.
2. Water can condense in the pipeline, causing slug flow and possible erosion and corrosion.
3. Water vapor increases the volume and decreases the heating value of the gas.
4. Sales gas contracts and/or pipeline specifications often have to meet the maximum water content of 7 lb H2O per MMscf. [3]

Natural gas is commercially dehydrated in one of three main techniques mentioned here-under:

1. Absorption Glycol Dehydration
2. Adsorption Mole Sieve or Silica Gel
3. Condensation Refrigeration with Glycol Injection

In addition, there are other methods used for dehydration but these are not commonly used. These methods are:

1- Dehydration with Cacl2.

2- Dehydration by membrane permeation. [4]

All the dehydration methods mentioned above are discussed in full details later in this chapter.