



iJRASET

International Journal For Research in
Applied Science and Engineering Technology



INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: IX Month of publication: September 2022

DOI: <https://doi.org/10.22214/ijraset.2022.46551>

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Dynamic Design Evaluation of Helium Recovery and the Thermodynamics and Economics Utilization of Improved Project Viability from Sales Gas

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Abstract: Sales gas generally contains barely 0.05 percent helium, making recovery uneconomical. Currently available commercial helium sources range from 0.3 to 8% helium from natural gas reserves, with 0.3 percent being the economic recovery limit. This article compares the technical and economic viability of manufacturing Grade-A liquefied helium from sales gas with low helium contents utilizing combined NGL/NRU/HRU technology.

Keywords: Helium, Evaluation, Economics, Project, Sales Gas, Thermodynamics

I. INTRODUCTION

Helium is also produced as a by-product of LNG production. After the methane and other hydrocarbons are liquefied, the helium and nitrogen remain gaseous and may be economically removed. Because of this, the end flash gas from an LNG plant tends to include 10 times the helium from the Qatar North Field, resulting in a helium concentration of 0.50 mole percent. At this concentration, classical stand-alone helium recovery becomes cost-effective, as used in Qatar LNG plants.

In the absence of an LNG plant, a Nitrogen Recovery Unit (NRU) is required to concentrate the helium to a level suitable for purification and liquefaction. This adds to the project's expense. Alternatively, integrating the NGL/NRU/HRU decreases equipment count, optimizes temperature profiles, and minimizes recompression horsepower.

II. INTEGRATION OF NGL/NRU/HRU

This research focuses on maximizing thermodynamic and economic advantages of an integrated plant architecture to increase project viability. As shown in the diagrams below, a standalone and an integrated plant arrangement.

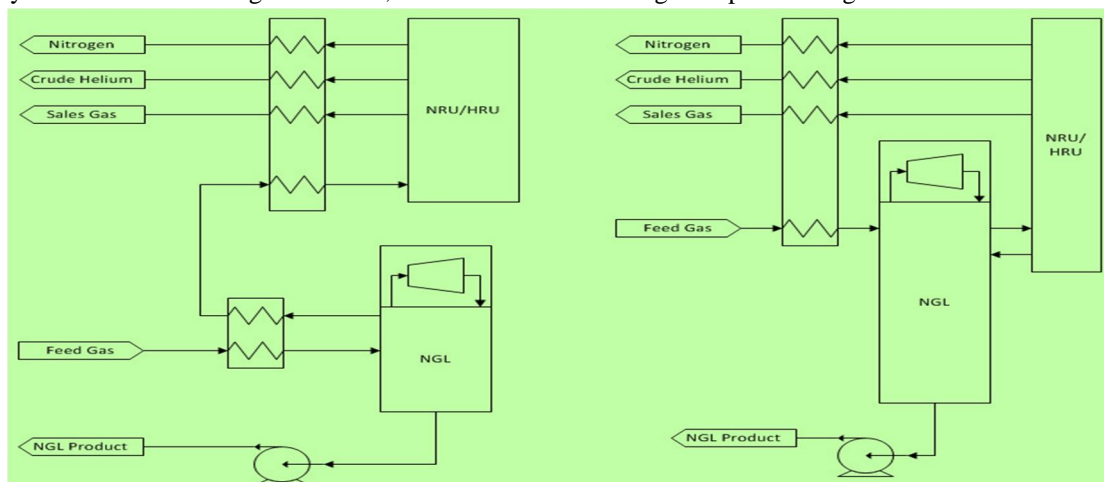


Fig 1: Distinct NGL and NRU/HRU

Fig 2: Integrated Setup

This results in high, moderate, and low pressure methane residual stream. This saves energy over combining an independent NGL backup system with a distinct nitrogen rejection unit. Less cool boxes and columns mean less recompression horsepower.

The Barzan Gas Project, a joint venture between Qatar Petroleum and ExxonMobil Barzan Limited, will be the first in Qatar to use Combined Natural Gas Liquids/Nitrogen Rejection Unit (NGL/NRU) technology. A comparable feed gas composition (0.05%) and overall sales gas flow (1.4Bscfd) are used in this project.

III. DESIGN PRINCIPLES

A. Composition of Feed Gas

Assuming a 95%+ ethane recovery rate, the feed compositions at the NGL Recovery Unit's output are shown in the following table. The gas is dry and devoid of mercury, with a CO₂ concentration of 50 parts per million (ppm) and an H₂S concentration of 4 parts per million (ppm).

Table 1: Helium Recovery Unit Feed

NGL Plant Gas Properties	
	NGL Recovery Outlet***
Pressure [Psig]	400
Temperature [°F]	140
MMSCFD**	1400
Component [Mole %]	
Nitrogen	8.168
Helium	0.050
CO ₂	0.002
H ₂ S	0.000
Methane	91.711
Ethane	0.069
Propane	0.001

IV. DESCRIPTION OF THE PROCESS

A. Description of Stand-Alone Process

As seen below, a standalone HRU may be installed downstream of an NGL Recovery Unit and upstream of Sales Gas Compression.

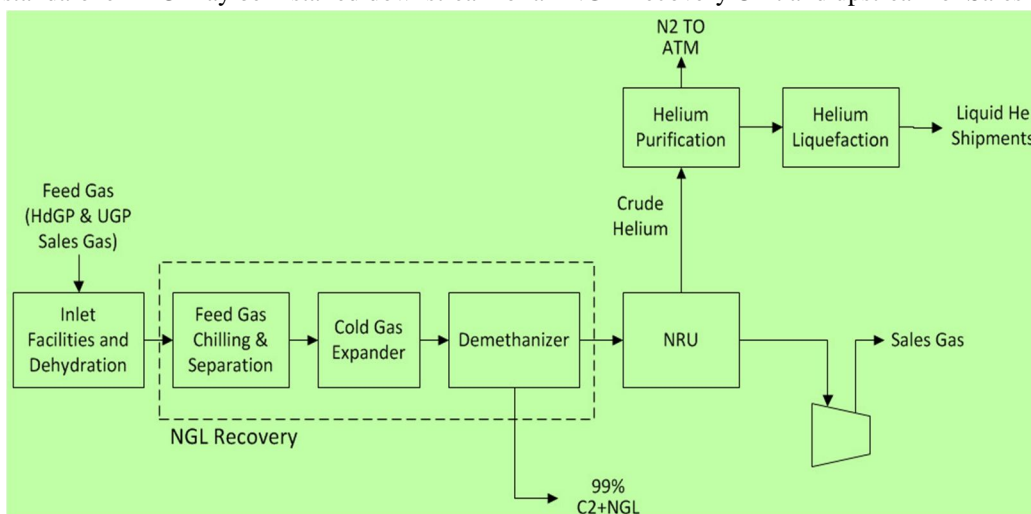


Fig 3: Standalone Helium Recovery

The overhead gas from the NGL Recovery Unit must first travel through a Nitrogen Rejection Unit (NRU) before proceeding to Helium Purification and Liquefaction. The freestanding Helium Recovery Unit is described below. Variations in process explanations from various licensors.

B. Nitrogen Recovery Unit

In the NRU, a high pressure pre-fractionator precedes a low pressure NRU fractionator. The NRU feed is the Demethanizer's overhead, which is chilled in a cryogenic heat exchanger and sent to the Prefractionator for nitrogen enrichment.

The prefractionator's bottom produces MP Sales Gas, while the prefractionator's overhead holds most of the helium. This vapor feeds the Low Pressure NRU Fractionator, which generates LP Sales Gas, nitrogen, and crude helium.

The nitrogen may be utilized for sealing, blanketing, purging, and cooling while the remainder is vented to the atmosphere. The Sales Gas Compressors receive the MP and LP Sales Gas. Because the NRU reduces pressure, the duty needed for the Sales Gas Compressors is increased compared to the present design.

The NRU's crude helium product is sent directly to the Helium Purification and Liquefaction Units..

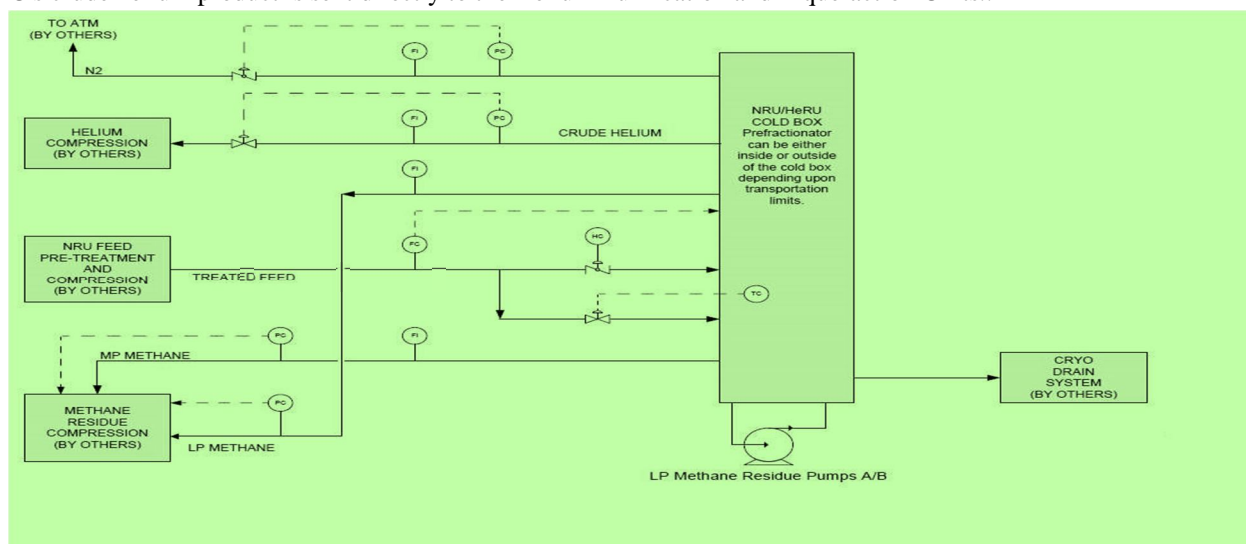


Fig 4: 2 Column Prefractionator for Nitrogen Rejection/Helium Recovery

C. Upgrade and Purification of Helium

To avoid freezing out contaminants in the liquefaction process, the NRU's crude helium must be upgraded to above 99 percent He before liquefaction. A PSA unit removes pollutants downstream of the NRU by condensation of H₂O, CO₂ and O₂.

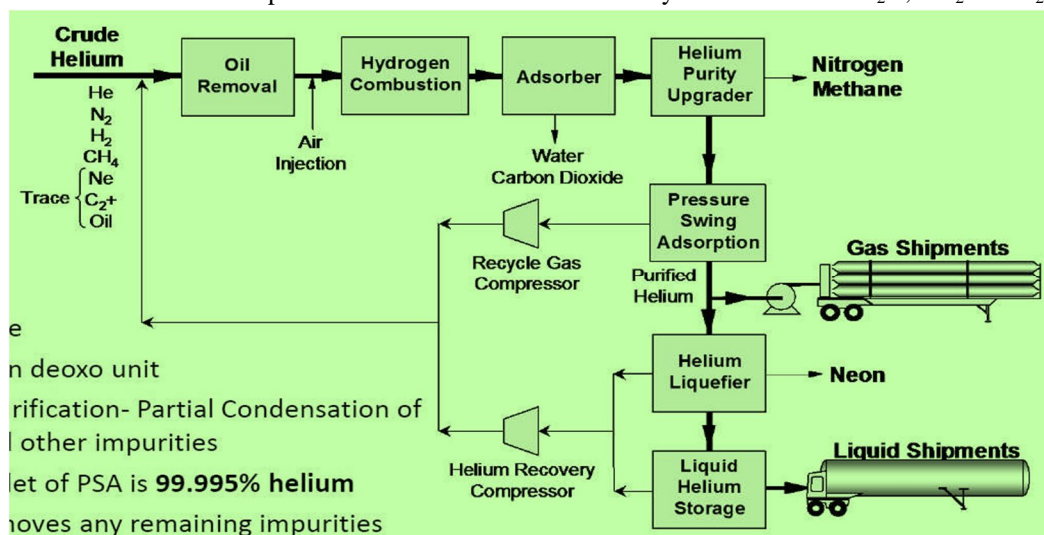


Fig 5: Upgrade and Purification of Helium

D. Liquefaction of Helium

To the Helium Liquefaction Unit with pure helium. The Helium Liquefaction device has two compressing segments (high- and low pressure) and a turbo-expander-equipped cold box. The helium cycle of compression, cryogenic expansion, and cryogenic heat transfer cools and liquefies the PSA unit's pure helium flow.

Produced liquid helium is stored in a tank. Recycled helium liquefaction tank vapor.

E. Integrated Helium Recovery Process Description

One provider recommended combining the Helium Recovery Unit with the NGL Recovery Unit, as seen in Figure 6. This integration may minimize overall equipment count and boost process efficiency. The feed stream is piped from Molsieve Beds to the integrated NGL/NRU Equipment.



Fig 6: Integrated NGL/NRU/HRU Helium Recovery

Also, it provides final separations of the methane residual streams and NGL products, and provides a “cooled” and “lean” feed to the high pressure column system. A part of the feed is utilized as a reboiler in the Demethanizer stage. A large amount is exchanged with NRU vapor product streams and partly condensed. A separator separates the bottom liquids from the partly condensed streams for the demethanizer.

As a result, a methane residue stream and a C₂+NGL liquid bottom stream with 99 percent ethane recovery are produced. The HP Column, absorber-stripper, works to separate and recover the extra ethane and heavier hydrocarbons while minimizing the nitrogen. The feed gas is then supplied to the NRU system, which begins with Prefractionator unit.

The NRU uses a Prefractionator to separate nitrogen and methane. This separation produces a methane-rich liquid that transports any leftover NGL components to the demethanizer. The net overhead vapor is also nitrogen-enriched and delivered to the NRU Fractionator.

The NGL/NRU unit's NRU Fractionator mechanism separates nitrogen from methane. The bottom methane goes to the demethanizer. The helium-rich overhead nitrogen product is transported to the Crude Helium Separator. Airborne crude helium from the Crude Helium Separator heads for purification and liquefaction. The purification and liquefaction units will function as detailed in the separate process description.

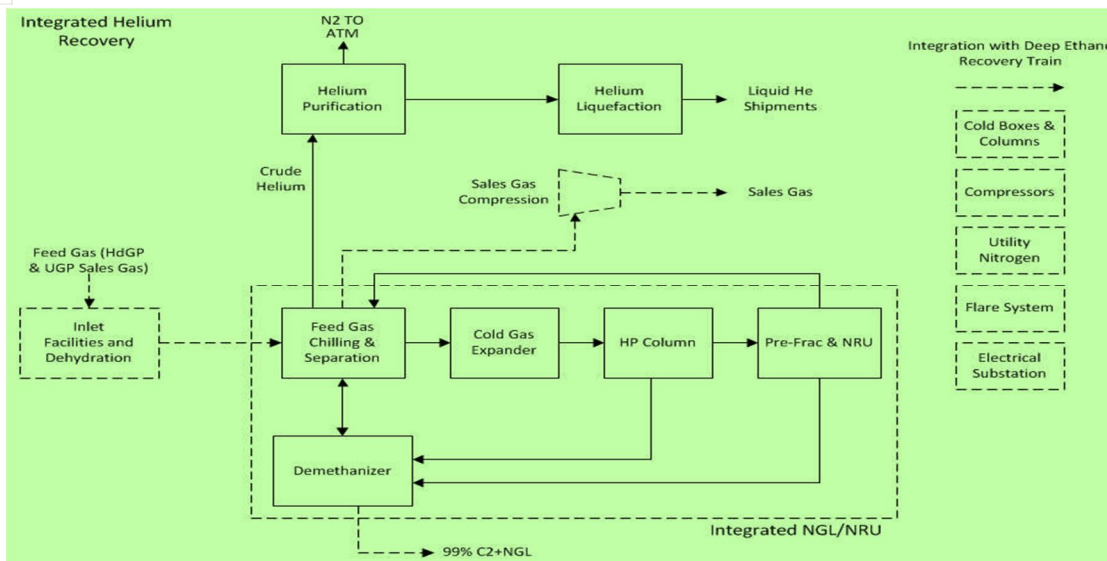


Fig 7: Process for Recovering Helium

V. COST EVALUATION BASED ON CLASS 5 RULES

In this research, the Total Installed Cost (TIC) estimations were based on equipment pricing and benchmarks from other projects. Cost estimates for bulks, piperacks, interconnections and buildings, transportation and construction management were generated based on the equipment costs supplied by the licensees. DCS/ESD/FGS and Flare were included in the screening TIC estimates as well as any items rejected by the licensors.

A. Estimated Costs

- 1) *Estimation of Stand-Alone Cost:* The stand-alone Helium Recovery Unit (HRU) has a CAPEX of \$216 million. The Total Installed Cost of the Helium Recovery Unit and the cost of the sales gas compressors are included in this calculation.
- 2) *Estimation of Integrated Cost:* The total cost of the Helium Recovery Unit is \$249 million. The Helium Recovery Unit's TIC and the sales gas compressors are both included in this price.

B. Economics of the Project

Revenue, CAPEX, OPEX, NPV, and IRR were estimated at the screening level for both stand-alone and integrated options. The results are shown in the table below. CAPEX/OPEX was based on bids from technology suppliers. Section 1.6 provides the basis for the estimations.

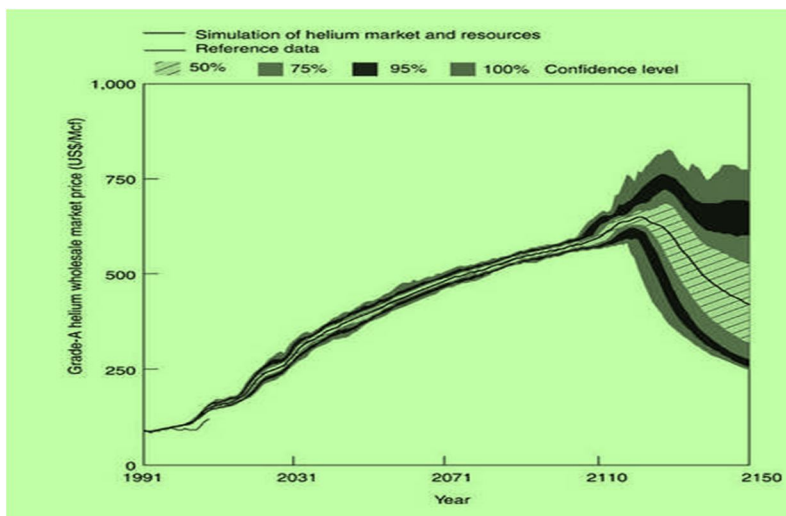


Fig 8: Grade A Real Price Trends in the Future

At \$100, \$150, and \$200/Mcf, helium prices are used to calculate the net profit. Technology vendors provided input towards CAPEX, which was then compared to comparable recent projects. Ongoing operational expenses were determined by licensors, with recompression charges accounting for the greatest portion.

The economics of the project are based on the foundations listed below:

Table 2: Economics Summary of the Project - Helium Plant						
Helium Price, \$/Mcf	NRU Configuration	Net Revenue, \$MM/yr	CAPEX, \$MM	NPV, \$MM	IRR, %	
100	Stand-Alone	(9)	(216)	(338)	N/A	
	Integrated	9	(249)	(120)	(0.7)	
150	Stand-Alone	4	(216)	(156)	(4.9)	
	Integrated	22	(249)	62	7.2	
200	Stand-Alone	17	(216)	25	6.0	
	Integrated	35	(249)	243	13.2	

Basis:

Helium production=256MMscfy

Grade- A helium (99.997%) liquefied product priced at: \$100/Mcf, \$150/Mcf and \$200/Mcf.

Cost of power=7cents/kWh

Discount rate=5%

VI. SUMMARY OF UTILITY

Table 3: Configuration of Stand-Alone	
	Total Power (BHP)
Sales Gas	148,250
Nitrogen Refrigeration	22,127
Misc. Compression	6,437
Total BHP	176,814

Table 4: Configuration of Integrated	
	Total Power (BHP)
Sales Gas	124,677
Nitrogen Refrigeration	5,000
Misc. Compression	6,437
Total BHP	136,114

VII. HYBRID & MEMBRANE TECHNOLOGY

Membrane technique for helium recovery from natural gas has been studied for many years, with multiple patents obtained. Several US government-funded initiatives are actively working on developing membrane technology for economically recovering helium from marginal gas reserves with low helium contents. According to top technology vendors, there is no reference facility utilizing membranes for helium recovery.

Membranes are suitable for numerous processes. If helium recovery is the main objective, helium concentrations greater than 0.5 percent are necessary. The 500ppm helium sales gas is too low for the present economic recovery.

Even at 0.5 percent concentration, a multi-stage design with separators and recirculation circuits is necessary. Even then, only a crude helium product is obtained, necessitating additional purification. The recovered helium is 30% helium, compared to 50-70 percent in most cases.

A. Hybrid Option

To achieve a hybrid approach, crude helium recovery may be achieved using membrane technology, followed by cryogenic separation and liquefaction. In one European facility, only membranes are used to decrease helium concentration from 0.4 percent to 80 percent recovery in a 120 MMSCFD gas stream. The recovered gas will be sent to a helium refinery with additional capacity to handle the crude helium stream, therefore purity is not crucial to the customer.

Membrane technology is not cost effective for this project, say two top providers. The low helium concentration and considerable gas flow need enormous membrane surface area.



Fig 8: Conventional Helium Recovery – Helium Project of Rasgas

VIII. KEY POINTS

- 1) This feasibility study indicates that helium recovery from sales gas is not economically viable using conventional cryogenic technologies. The primary reason is that due to the low helium concentration, a NRU is needed to concentrate it to higher levels for economic removal.
- 2) Amongst the technology options considered in this study, the NGL/NRU/HR integration technology looks most promising. In this option the NRU is integrated with the NGL unit reducing CAPEX and OPEX as some equipment is eliminated and recompression costs reduced due to thermodynamic advantages.

IX. CONCLUSION

- 1) An integrated NGL/NRU/HRU Helium Plant can extract helium from sales gas.
- 2) A commercial helium extraction plant processing 260MMscfy of total gas feedstock costs \$280MM. This plant's CAPEX is projected at \$249MM.
- 3) OPEX for standalone and integrated alternatives is \$34MM and \$17MM, respectively.
- 4) At a helium price of \$200/Mscf, the gross revenue is \$17MM for standalone and \$35MM for integrated.
- 5) At \$200/Mscf, the NPV of such a project is \$25MM for stand-alone and \$243MM for integrated alternatives. The IRRs are 6.0 and 13.2 percent.
- 6) In 2020, the Future Trend in Real Price of Grade A indicates helium at \$230-240/Mscf.
- 7) Membrane technique is not possible owing to low helium concentration and huge gas volume. Also, a hybrid method including membranes to produce crude helium, followed by cryogenic purification and liquefaction, is not practicable.

X. ACKNOWLEDGEMENT

I thank co-authors for their expertise and assistance throughout all aspects of this research work.



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