

# **HELIUM LIQUEFIER SYSTEM REPORT**

Undergraduate Student: Fernanda Cavalcante da Silva

Professor: Dan Lathrop

Institute for Research in Electronics and Applied Physics

University of Maryland

2015

## TABLET OF CONTENTS

<b>1. ABSTRACT.....</b>	<b>2</b>
<b>2. INTRODUCTION.....</b>	<b>2</b>
<b>3. HELIUM LIQUEFIER SYSTEM .....</b>	<b>2</b>
<b>4. COMPONENTS .....</b>	<b>3</b>
<b>4.1. Recovery Bag .....</b>	<b>3</b>
<b>4.1.1. Function .....</b>	<b>4</b>
<b>4.1.2. Required size of the bag storage .....</b>	<b>4</b>
<b>4.1.3. Quotations .....</b>	<b>4</b>
<b>4.1.4. Examples of how to hold the gas helium bag .....</b>	<b>5</b>
<b>4.2. Compressor .....</b>	<b>6</b>
<b>4.2.1. Quotations .....</b>	<b>6</b>
<b>4.3. Helium Purifier .....</b>	<b>7</b>
<b>4.3.1. Quotations .....</b>	<b>8</b>
<b>4.4. Helium Liquefier .....</b>	<b>8</b>
<b>4.4.1. Liquefier Ordered .....</b>	<b>8</b>

## 1. ABSTRACT

As a non-renewable resource, reutilizing Helium is of great interest. Differently from other non-renewable resources such as oil, once released into the atmosphere it travels up into the upper part of the atmosphere and escapes into space, and once it has gone we can never get it back. The development of a system that captures, filtrates, and repurposes used helium is a valuable asset for research. This report provides a summary of how the recovery of helium works with considerations of the system for our lab.

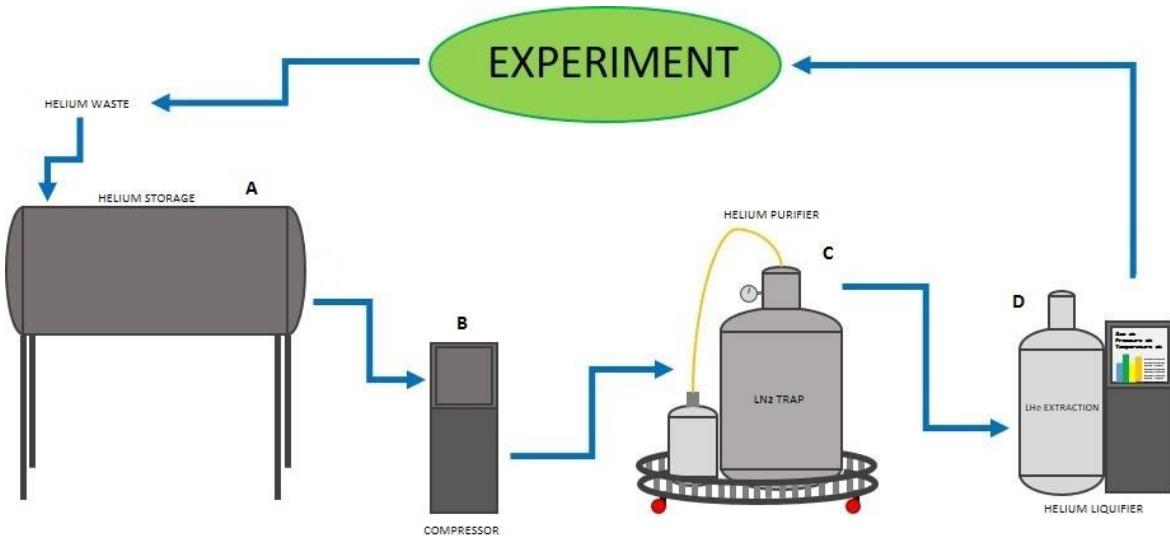
## 2. INTRODUCTION

Helium is an essential element in the operation of several low-temperature instrumentation applications such as nuclear magnetic resonance (NMR) spectrometers, magnetoencephalography (MEG) scanners, magnetic resonance imaging (MRI) scanners, and other assorted research cryostats. Even though Helium is the second most abundant element in the observable universe, Helium is relatively rare on earth. Today, many labs still depend on external deliveries of helium storage tanks, and because of the increase in demand for liquid helium worldwide the supply is scarce, and consequently the price has increased. Therefore, many researchers and laboratories are motivated to make helium recycling a relevant project in their facilities' infrastructure. The Helium liquefier is an open cycle process system where warm pure helium gas enters the system and is refrigerated to produce a pure liquid helium product stream. Currently, several industries are specialized in designing the entire helium liquefier system. Some systems can provide over 100 liters per hour with a highly efficient process cycle. Our lab has designed a High Pressure Recovery system, which performs on a helium liquefier model LHeP22 from Cryomech.

## 3. HELIUM LIQUEFIER SYSTEM

The Recovery System with high pressure storage consists basically of the following components:

- A- Helium Gas Bag
- B- Compressor
- C- Helium Purifier
- D- Helium Liquefier



*Figure 1. Helium Liquefier Diagram.*

The helium system allows us to collect the helium that goes out of the experiment, purify it, reliquefy it, and then put it back into the experiment. As shown in the diagram above, first, the helium is stored in a recovery bag. The Recovery Bag is made of a durable vinyl-based polymer material, and it has a Laser positioning sensors that start automatically the recovery compressor when the bag is full and stop the compressor when the bag is empty. Then, the gas goes to a purifier.

Purifying the gas will maximize the running time of the liquefier and reduce the down time for maintenance. The high purity is created by combining a cryogenic purifier and an all-metal system to prevent O<sub>2</sub> or H<sub>2</sub>O contamination. Finally, the gas goes to the liquefier. Helium gas enters the liquefier at room temperature and it is first precooled by heat exchange with the first stage of the cold head to a temperature typically between 40 and 60 K. Then, the helium gas continues on its way down and is further cooled by heat exchange with the second stage, until the condensation temperature is reached when it converts into liquid.

## 4. COMPONENTS

### 4.1. Recovery Bag

The Recovery Bag is made of a durable vinyl-based polymer material. The output of the bag interfaces with the helium purifier, and then into helium re-liquefier.

#### *4.1.1. Function*

The bag accepts vaporized helium gas from experimental cryostats, detectors, and magnet systems which is routed through home-built manifolds and piping. Laser positioning sensors automatically start the recovery compressor when the bag is full and stop the compressor when the bag is empty.

#### *4.1.2. Required size of the bag storage*

Use of liquid helium: 25 liters/day  $L^4He$ ; 8 – 10/month

Volume of 1atm helium in a day: Gas volume:  $18.325\ m^3 = 18325\ \text{liters}$

For the usage of a 100 liters  $L^4He$  dwell:

Bag minimum volume at 1 atm =  $2588.57\ \text{ft}^3 = 73.3\ m^3$

Bag has to support at least 27.3 lb = 12.4 kg

#### *4.1.3. Quotations*

According to the **Quotation (A)** (see List of Quotations) from Hopikins Liquefier (Department of physics) note:

Gas bag dimensions:  $3408.44\ \text{ft}^3 = 96.5\ m^3$

Bag's price: \$19,245.00

Company: ATL Aero Tec Laboratories: <http://www.atlinc.com/inflatables.html#GAS>

According to the **Quotation (B)** asked for IREAP note:

Gas bag dimensions:  $3566.78\ \text{ft}^3 = 101\ m^3$

Bag's price + Sensor on gas bag for automatic blower control: \$13152.00

Company: Quantum Technology Corp: <http://quantum-technology.com/recover/equipment/gas-bags.html>

The weight of a  $101\ m^3$  bag is about 214 kg.

The weight of a high quality  $101\ m^3$  bag is about 156 kg.

According to the **Quotation (C)** asked for IREAP note:

Gas bag dimensions:  $4025.8 \text{ ft}^3 = 114 \text{ m}^3$

Bag's price: \$27,718.96

Company: ATL Aero Tec Laboratories: <http://www.atlinc.com/inflatables.html#GAS>

The weight of a  $116 \text{ m}^3$  bag is about 236 kg.

The weight of a high quality  $116 \text{ m}^3$  bag is about 171 kg.

#### *4.1.4. Examples of how to hold the gas helium bag (pictures taken from google images)*





**PS:** High quality rubber is light in weight; however, it only triggers the compressor when it is very full and does not pump out completely.

**Hint:** frame from PVC tubing resting on top of the bag to add extra pressure.

#### 4.2. Compressor

The Compressor is single-stage, water-cooled, rotary, designed to deliver high-pressure, oil-free Helium gas to the purifier.

##### 4.2.1. Quotations

According to the **Quotation (B)** asked for IREAP note:

Helium High Pressure Compressor: Model Q-09.4-hrp-7.1

Pressure: 4500 psi

Flow rate: 7.0 cfm

Motor size: 7.5 HP

Cooling: Air cooled

Electric powered: 3 phase, motor as per customer order

Compressor's price: \$25250.00

Company: Quantum Technology Corp: <http://quantum-technology.com/>

### Used Compressor

Asst. Prof. Bruce E. Rodenborn from the Physics Department is selling the following compressor:

Compressor Model: ARS-4HW

Company: Advanced Research Systems: <http://www.arscryo.com/Products/cryogenic-accessories/Compressors/ARS-4HW.html>

Compressor's price: not decided

The figure below is the ARS-4HW Compressor specifications.

### Compressor Specifications

<b>Compressor Model</b>		<b>ARS-4HW</b>	
<b>Standard Voltage</b>	Frequency	60 Hz	50 Hz
	Min	208 V	190 V
	Max	230 V	210 V
<b>Transformer Options</b>	10%	220 V, 230 V	
	15%	240 V	
<b>Power Usage</b>	Singe Phase	3.6 kW	3.0 kW
<b>Refrigerant Gas</b>		99.999% helium gas, pre-charged	
<b>Noise Level</b>		60 dBA	
<b>Ambient Temperature</b>		12 - 40 C (54-104 F)	
<b>Cooling Water</b>	Consumption	1.5 L / min (0.4 Gal. / min)	
	Temperature	10 - 35 C (50-95 F)	
	Connection	3/8 in. Swagelok fitting	
<b>Dimensions:</b>	L	483 mm (19 in)	
	W	434 mm (17.1 in)	
	H	516 mm (20.3 in)	
<b>Weight</b>	Compressor	72 kg (160 lbs)	
<b>Typical Maintenance Cycle</b>		12,000 hours	
<b>Water Recirculation Option</b>		CoolPac compatible	

Figure 2. ARS-4HW Compressor Specifications.

### 4.3. Helium Purifier

Purifying the gas will maximize the running time of the liquefier and reduce the down time for maintenance. The high purity is created by combining a cryogenic purifier and an all-metal system to prevent O<sub>2</sub> or H<sub>2</sub>O contamination.

### *4.3.1. Quotations*

According to the **Quotation (B)** asked for IREAP note:

Helium Purifier: Model Q16.1-QUANTUMPURE

#### **Removable LN2 Cold Trap Purifier**

Purifies the gas to ensure liquefaction of high purity Helium

Dimensions: 0.11 m diameter, 1.2 m high,

Liquid Nitrogen Dewar – 240 liters - with a wide neck

Purifier's price: \$17450.00

Purity Meter price: \$8,765.00

Company: Quantum Technology Corp: <http://quantum-technology.com/>

According to the **Quotation (D)** from Hopikins Liquefier (Department of physics) note:

Helium Purifier: Model: Q16.1QUANTUMPURE

Purifier + Purity meter + Shipping to UMD: \$21,600.00

Company: Quantum Technology: <http://quantum-technology.com/>

## **4.4. Helium Liquefier**

The Helium liquefier is an open cycle process system where warm pure helium gas enters the system and is refrigerated to produce a pure liquid helium product stream.

### *4.4.1. Liquefier Ordered*

The following liquefier has been ordered (see Liquid Helium Plant Specification Sheet for more details).

Liquefier Model: LHeP22

Produce > 22 liters/day

150L Dewar

PT415 Cryorefrigerator

Liquefier's price: \$93,459.00

How much cooling energy does the liquefier take?

Cooling the helium from the room temperature to 4.2 K requires 4602.1 kJ of energy.