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E781

Portable Neon Purification System

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PORTABLE NEON PURIFICATION SYSTEM*

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ABSTRACT

This paper describes the principle design features of a portable neon purification system and the results of the system performance testing. Neon gas replaces air in the Ring Imaging Cherenkov detector without using vacuum, in experiment E781(SELEX) at Fermilab. The portable neon purification system purifies neon gas by, first purging air with CO_2, freezing the CO_2, then cryoadsorbing the remaining contaminants. The freezer removes carbon dioxide from a neon gas mixture down to a maximum concentration of 500 parts-per-million (ppm). The charcoal bed adsorber removes nitrogen from neon gas down to a maximum concentration of 100 ppm. The original RICH vessel was designed to hold vacuum but its photomultiplier tube plates were not.

INTRODUCTION

The neon purification system was initiated as a cost effective means of removing air and replacing it with purified neon without using vacuum, in the phototube Ring Imaging Cherenkov (RICH) detector, for experiment E781 at Fermilab. The RICH vessel is unable to withstand vacuum due to the use of thin window plates containing approximately 2850 quartz windows. Consequently, a small positive pressure will be maintained in the RICH vessel. Experimental data on purifying neon gas by adsorption using activated coconut shell carbon as an adsorbent with our conditions, was not available.

The physics requirement for experiment E781 is to provide good charged particle identification during the next fixed target run. Their goals includes high efficiency detection of the generated photons and good ring radius resolution. [1] The presence of oxygen and water vapor contaminants adsorb photons needed for particle identification.

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Therefore, a pure neon gas was selected because its refractive index is acceptable for particle identification, at the selected particle velocity.

SYSTEM DESCRIPTION

The neon purification system purifies neon gas to remove O_2 and water vapor contaminants. Initially, the RICH is filled with air. Cylinders of CO_2, with a densities greater than that of air, are introduced into the bottom of the vessel, to purge air out the top of the vessel and discharged to atmosphere. Neon gas is introduced at the top of the RICH and purges CO_2 out the bottom. The freezer is then used to remove CO_2 from the neon, followed by the adsorber which is used to remove all remaining contaminants. Care is taken not to waste the expensive neon gas. The system design objective is to reach a maximum contamination of 500 ppm CO_2 and 100 ppm O_2 within 24 hours.

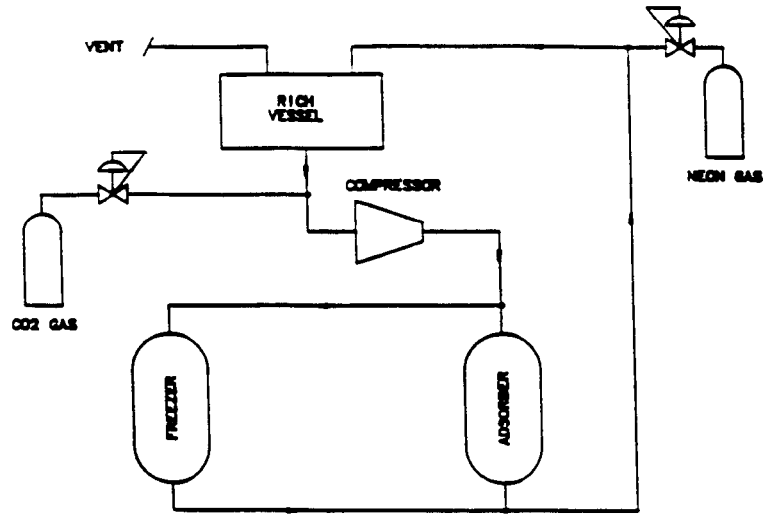

Figure 1. Neon Purification System Flow Schematic.

Components

The major purification system components and their associated piping are housed on a 0.914 m x 1.12 m x 1.80 m portable skid. The system'components consist of (1) a freezer, used to remove carbon dioxide and water vapor; (2) a heat exchanger, to achieve required temperatures; (3) an adsorber, to remove oxygen from the neon gas mixture and (4) the RICH, a 43.6m^3(1540 ft^3) carbon steel vessel and associated instrumentation. Several 160 liters of LN_2 dewars supply the adsorber jacket at 2.5 atm and 84 K. A 15 hp Corken, two stage gas compressor, which compresses and flows neon gas into the adsorber, via a heat exchanger, to pressures of approximately 9.5 atm.

Instrumentation and Controls

A Fischer & Porter (F&P) controller use a custom valve positioner box, controls the actuation of two Fermi-built control valves. One valve controls the flow of liquid nitrogen to the freezer, to achieve and maintain temperatures. The F&P controller monitors and controls the temperature of the freezing process, by the signal it receives from a resistance temperature device (RTD). The second actuator valve controls the level in the adsorber liquid nitrogen jacket. The F&P controller also monitors the temperature of the adsorption process from the signal it receives, from an RTD, located inside the charcoal bed. The controls instrumentation, as well as the Rosemont CO_2 and Teledyne O_2 gas analyzers, are located on an instrumentation rack, near the purification skid.

THEORETICAL DESIGN RESULTS

Freezer

The density of CO_2 is greater than that of air so, initially CO_2 will be introduced from the bottom of the vessel to purge air from the top of the RICH, to atmosphere. Neon gas is introduced into the top of the RICH to purge CO_2 out the bottom. CO_2 and neon enters the compressor, then the freezer, where CO2 and water vapor are frozen out. The freezer was designed as a counter flow heat exchanger using the NTU and LMTD methods. It is a 0.305 m OD pressure vessel constructed of 304 stainless steel. Its volume is sized at 0.141 m^3 (5 ft^3), contains 0.203 m OD and 0.254 m OD helical wound copper cooling coils (125 turns each) and a 0.152m OD excluder that directs the flow of gas. The freezer is insulated with 0.076 m (3 in) of Armaflex foam insulation. This unit was designed to remove carbon dioxide, at minimum, one-half the vessel volume 21.8 sccm (770 scf) from the neon gas mixture to a maximum concentration of 500 ppm and to operate at pressures and temperatures below 13.2 atm and 193K, respectively. Table 1 contains parameters used in the design of the freezer:

Table 1. Freezer Design Data.

	CO_2 Inlet	LN_2 Inlet
Pressure	1.0 atm	2.7 atm
Temperature	294 K	84 K
Fluid Density	1.83 kg/m^3	7.30 kg/m^3
Mass Flow Rate	0.047 kg/s	0.09 kg/s

Adsorber

The gas flowing during the process enters downward, to minimize adsorbent movement and pressure-drop through the bed, into the charcoal bed under isobaric and isothermal conditions. The bed design is critical to the adsorption process. In this fixed bed adsorber design, the most critical factors to size were the required volume of adsorbent and gas velocity, which typically result in height to diameter ratio of about 2:1 and velocities between 0.15 m/s and 0.50 m/s based on an empty vessel. In this design the pressure-drop of the gas flowing through the bed was calculated using the following generalized pressure-drop correlation given by

$$\frac{\Delta P}{L} = \frac{fC_t^2 G^2}{\rho D_p} \quad (1)$$

where C_t is the pressure drop coefficient, Dp is the effective particle diameter, ft is the friction factor, G is superficial mass velocity, L is the distance from the bed entrance, ΔP is pressure drop, ρ is fluid density and $\Delta P/L$ is the pressure drop per unit length of the bed. [2] The adsorber design data is listed in Table 2 as follows:

Table 2. Adsorber Design Data.

Volumetric Flow Rate	1529 slpm
Gas Flow Velocity	849 slpm
Operating Pressure	9.5 atm
Operating Temperature	77 K
Neon Gas Density	31.1 kg/m^3
Initial Contamination Level	3% N_2
On-Stream Time	10 hours
Bed Pressure Drop	1.2 atm
Bed Height to Diameter Ratio	2
Required Desiccant Area	0.167 m^2
Required Volume of Adsorbent	0.51m^3

The resulting adsorber is a 0.458 m O.D. pressure vessel, constructed of 304 stainless steel. Its volume is sized at 0.153 m^3 (5.4 ft^3), it is filled with 64 kg of type PCB (4X8 mesh) activated coconut-shell carbon, contains four 600 watt heaters for adsorber regeneration and is equipped with an outside liquid nitrogen jacket. The adsorber is insulated with 0.076 m (3 in) Armaflex foam insulation. This component was designed to remove a minimum of 1.31 m^3 (46.2 scf) of nitrogen (3% of RICH volume) from a neon gas mixture down to a maximum concentration of 100 ppm, operate at a temperature of 77K, a pressure of 9.5 atm (125 psig) and a gas flowrate of 1529 slpm (54 scfm). Several 160 liters of LN_2 dewars supply the adsorber jacket at 2.5 atm and 84 K. A 15 hp Corken two stage gas compressor compresses and flow neon gas into a heat exchanger and adsorber, to pressures of approximately 10.5 atm.

EXPERIMENTAL PERFORMANCE RESULTS

Freezer

Performance testing was conducted to determine the performance characteristics of the neon purification system freezer. The objective of this test was to determine the amount of pure carbon dioxide the freezer could freeze. The first test was conducted using a small 0.934 sccm (33 scf) vessel. The test results indicated that the neon purification system freezer's capacity is 29.7 scm (1048 scf) of pure carbon dioxide, at an operating pressure of 9.5 atm (126 psig), temperatures below 193 K and a gas flowrate of 339 slpm (12 scfm).

A final performance testing was performed whereby, the actual RICH vessel, filled with air, was purged with carbon dioxide gas. Neon gas was then introduced to purge one-half the carbon dioxide volume out the vessel, before starting the compressor. To begin the

freezing process, liquid nitrogen was allowed to flow through the cooling coils. The RICH was maintained at pressures up to 1.13 atm (2 psig).

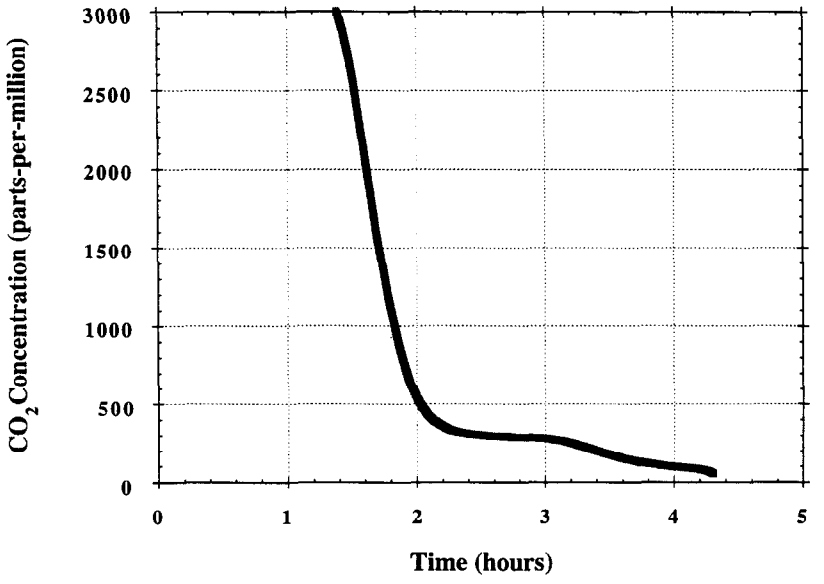

Figure 2. Freezer Purification Rate.

The compressor compressed and circulated the gas mixture to an average system pressure of 9.6 atm, which stabilized the system at an average flowrate of 425 slpm (15 scfm) and freezer temperatures below 123 K (-238 °F). The freezer removed about 22.54 scm (800 scf) of CO_2, from the Ne-CO_2 mixture, down to 300 ppm. The performance data is presented in Figure 2:

Adsorber

Initially, the adsorber capacity was determined through testing. The RICH was maintained at pressures between 1.03 and 1.14 atm. Several 160 liters of LN_2 dewars were used to supply the adsorber jacket at 2.5 atm (22 psig) and 84 K. Initially, the jacket was filled to the 75% level. The gas compressor was used to compress and flow neon gas into the adsorber, via a heat exchanger, to pressures of approximately 10.5 atm. Due to the unavailability of an O_2 analyzer, nitrogen gas analyzer was used. N_2 is more difficult to remove, from neon gas, than O_2. The adsorption process was monitored and the system operated until the adsorber capacity, the breakthrough point, was reached. The breakthrough point was the point at which the adsorber became saturated, which occurred at 131 ppm N_2 in less than 3 hours, after 570 scf of N_2 were added.

The Teledyne O_2 analyzer was used during the final adsorber performance test to monitor the O_2 content in the neon gas. The adsorber removed oxygen from neon gas in the RICH to a contamination level of less than 2 ppm. The average system pressure was

9.8 atm (130 psig) and flowrate of 510 slpm (18 scfm). Figure 3 represents the rate at which the adsorber removed O_2 from neon:

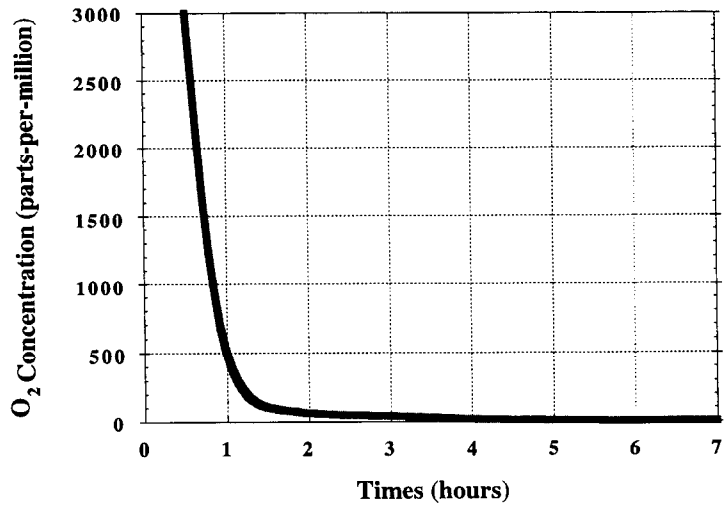

Figure 3. Adsorber Purification Rate

COMPARISON OF RESULTS

The freezer was designed to freezer 21.7 m (770 ft^3) of CO_2 from neon gas, at a pressure less than 13.2 atm (180 psig) and temperatures lower than 193 K, to a maximum contamination level of 500 ppm. The initial performance test results indicate that the freezer is capable of freezing (1048 scf) of pure CO_2. The final test results, show that the freezer is capable of freezing out CO_2 from neon gas at an average pressure of 9.6 atm (127 psig), at temperature below 123 K and at an average flowrate of 425 slpm (15 scfm) to a concentration level of 300 ppm.

The adsorber was designed to remove a minimum of 131 scm (46.2 scf) of nitrogen from a neon gas mixture down to a maximum concentration of 100 ppm, operate at a temperature of 77K, a pressure of 10 atmospheres and a gas flowrate of 1529 slpm (54 scfm). The adsorber capacity was determined to be 570 scf of N_2. As a reult of the final performance testing, the adsorber removed oxygen from neon gas to a contamination level of less than 2 ppm at an average system pressure was 9.8 atm (130 psig) and flowrate of 510 slpm (18 scfm).

Experimental data on purifying neon gas by adsorption, using activated carbon with our conditions, was not available. The portable purification system was successful at freezing out CO_2 to less than 500 ppm CO_2, followed by cryoadsorbing the remaining contaminants to a concentration level less than 2 ppm O_2.

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